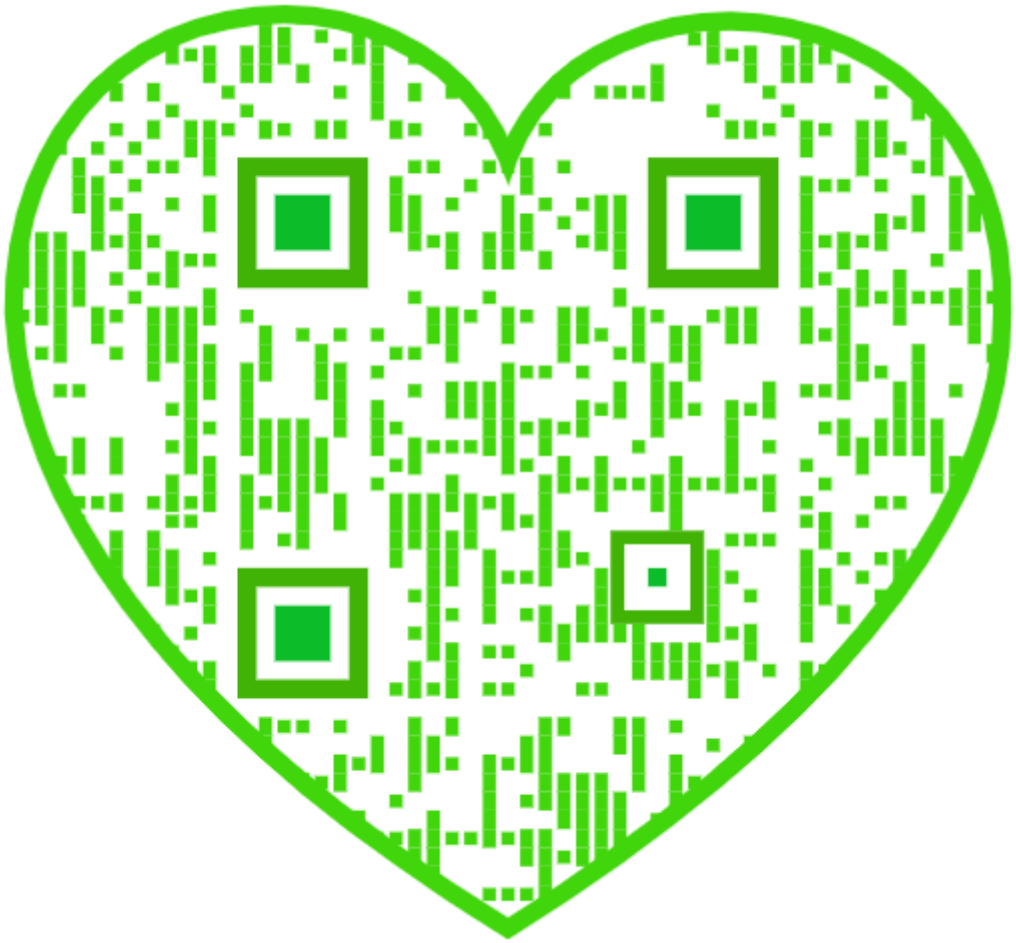

LABORATORY EXERCISES

ARRANGED TO ACCOMPANY "FIRST COURSE IN CHEMISTRY"

BY

WILLIAM McPHERSON

AND

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PREFACE

It is no longer necessary to emphasize the importance of laboratory work as a part of the course in elementary chemistry, since it is universally admitted that laboratory experience is essential for a thorough comprehension of the subject. It is none the less true, however, that laboratory work is of little value unless carefully directed by an experienced teacher toward some definite end. It is in the hope of aiding such a teacher that this exercise book has been prepared. The exercises are arranged to accompany McPherson and Henderson's "First Course in Chemistry."

While the experiments described may be performed with simple apparatus and inexpensive materials, nevertheless it is believed that they will serve to give the student a good insight into the elementary principles of chemistry as well as into many of the applications of the science.

Detailed information as to the apparatus and materials required for performing the experiments will be found in the Appendix.

OHIO STATE UNIVERSITY
COLUMBUS, OHIO

CONTENTS

EXERCISE		PAGE
1.	The Metric System; the Bunsen Burner	1
2.	A Study of Some of the Changes taking place when a Substance Burns	3
3.	Chemical Compounds; Elements; Chemical Changes; Chemical Affinity	5
4.	The Manipulation of Glass Tubing	6
5.	The Collection of Gases; the Preparation of Oxygen	9
6.	The Preparation and Properties of Oxygen	10
7.	Some Further Preliminary Manipulations	12
8.	The Preparation and Properties of Hydrogen	14
9.	The Combustion of Hydrogen; the Oxyhydrogen Blowpipe	17
10.	Measurement of Gas Volumes (Optional)	18
11.	A Study of the Process of Distillation	19
12.	The Qualitative Synthesis of Water; Oxidation and Reduction	21
13.	The Properties of Hydrogen Peroxide	22
14.	Boiling Points and Freezing Points	23
15.	The Determination of the Weight of One Liter of Oxygen; also the Determination of the Percentage of Oxygen in Potassium Chlorate (Quantitative) (Optional)	24
16.	The Determination of the Amount of Hydrogen Displaced by a Definite Weight of Different Metals (Quantitative) (Optional)	26
17.	The Preparation and Properties of Nitrogen	28
18.	The Composition of Air (Quantitative)	29
19.	A Study of Solutions	31
20.	The Determination of the Solubility of Common Salt (Quantitative)	32
21.	A Method for Determining whether or not a Given Liquid is a Conductor of Electricity (Optional)	33
22.	The Properties of Acids, Bases, and Salts	34
23.	The Ratio of Acid to Base in Neutralization (Quantitative)	35

EXERCISE PAGE
24. The Displacement of Metals from their Compounds 36
25. Valence 37
26. The Preparation and Properties of Ammonia 37
27. The Preparation and Properties of Nitric Acid 39
28. The Properties of the Salts of Nitric Acid (Nitrates) . . . 41
29. The Preparation and Properties of Some of the Oxides of Nitrogen 42
30. Reversible Reactions; Hydrolysis 43
31. The Properties of Sulfur 43
32. The Preparation and Properties of Hydrogen Sulfide . . . 45
33. The Preparation and Properties of the Salts of Hydrosulfuric Acid (Sulfides) 46
34. Sulfur Dioxide and Sulfurous Acid 48
35. A Study of Sulfuric Acid 49
36. Salts of Sulfuric Acid (Sulfates) 50
37. The Preparation and Properties of Hydrogen Fluoride . . . 51
38. The Preparation and Properties of Chlorine 52
39. The Preparation and Properties of Hydrogen Chloride and of Hydrochloric Acid 54
40. The Test for Hydrochloric Acid and its Salts (Chlorides) . . 55
41. The Preparation and Properties of Bromine and of Hydrogen Bromide 56
42. The Preparation and Properties of Iodine and of Hydrogen Iodide 57
43. How to Distinguish between Chlorides, Bromides, and Iodides 58
44. Methods for Detecting the Salts of Certain Acids 59
45. The Formation of Charcoal and Coke 59
46. A Further Study of Carbon 60
47. A Study of Carbon Dioxide 61
48. Carbonic Acid and its Salts (Carbonates) 62
49. A Study of Carbon Monoxide (Optional) 63
50. A Study of Some of the Hydrocarbons 64
51. A Study of the Flame 65
52. A Study of the Sugars 67
53. A Study of Starch 68
54. A Study of Textile Fibers 69
55. The Preparation and Properties of Common Alcohol (Ethyl Alcohol) 70
56. The Determination of the Amount of Alcohol Present in an Alcoholic Liquid (Quantitative) (Optional) 72
57. The Action of Preservatives (Optional) 73

EXERCISE PAGE
58. A Study of Vinegar (Quantitative) (Optional) 74
59. The Preparation of a Simple Ester 75
60. Tests for Fats and for Proteins 76
61. The Composition of Flour 77
62. Some Further Experiments with Milk (Optional) 78
63. Methods for Distinguishing between Butter and Oleomargarine (Optional) 79
64. Phosphorus and its Compounds 80
65. Arsenic and Some of its Compounds 81
66. A Study of Some of the Properties of Antimony 82
67. A Study of Some of the Properties of Bismuth 82
68. Compounds of Silicon 83
69. Compounds of Boron 84
70. General Methods for the Preparation of the Compounds of the Metals 85
71. Sodium and its Compounds 86
72. The Determination of the Weight of Common Salt obtained by adding Hydrochloric Acid to a Definite Weight of Sodium Bicarbonate (Quantitative) (Optional) 88
73. The Test for Potassium; the Preparation of Potassium Nitrate 89
74. The Properties of Ammonium Compounds 90
75. Detection of Compounds of the Alkali Metals 91
76. The Preparation and Properties of Soap 91
77. A Study of Some of the Compounds of Calcium 92
78. Hard Waters and Methods for Softening them 94
79. Some Additional Experiments with Soap (Optional) . . . 95
80. The Preparation and Properties of Bleaching-Powder (Optional) 96
81. Magnesium and its Compounds 97
82. Zinc and its Compounds 98
83. Aluminium and its Compounds 99
84. A Study of the Use of Aluminium Sulfate in the Purification of Water 100
85. Reactions of Baking-Powders 100
86. Analysis of Baking-Powders (Optional) 101
87. The Use of Mordants in Dyeing 102
88. A Study of Lakes; also the Effect of using Different Mordants with the Same Dye (Optional) 104
89. The Detection of Dyes in Foods (Optional) 105
90. A Study of Iron and its Compounds 106
91. The Removal of Stains 107

EXERCISE PAGE

92. The Determination of the Amount of Water of Hydration in Copper Sulfate (Quantitative) 108
93. A Study of Copper and its Compounds 109
94. A Study of Mercury and its Compounds 110
95. A Study of Silver and its Compounds 111
96. Some Properties of Tin 112
97. A Study of Lead and Some of its Compounds 112
98. The Detection of Silver, Lead, and Mercury when Present in the Same Solution (Optional) 113
99. A Study of Some of the Compounds of Manganese (Optional) 114
100. A Study of Some of the Compounds of Chromium (Optional) 115
101. Borax-Bead Tests (Optional) 115

APPENDIX A 117

APPENDIX B 121

DIRECTIONS

It is not expected that each student will perform all the experiments described in the following pages. Some of them are marked "optional" and parts of others designated by a star (*) may be omitted if time for performing them is not available. A number of experiments on foods are included, and it may be that the teacher will find it of advantage to have the girls perform all of these while the boys are performing others of more immediate interest to them.

A list of the apparatus and chemicals necessary for performing the experiments, together with suggestions as to their purchase, is given in the Appendix. It is expected that each desk will be provided with five of the most common reagents (see Appendix). Other reagents used less frequently should be placed on a reagent shelf available to all. The abbreviation (R.S.) used in listing the materials necessary for performing each individual experiment refers to the reagents on the reagent shelf. The abbreviation (R) implies that the equation for the reaction involved in the experiment is to be written. The character (?) implies that the results obtained in that part of the experiment are to be recorded in the notes. The word *hood* signifies that the experiment is to be performed in a well-ventilated compartment so that any poisonous gases evolved will be removed at once. All thermometer readings refer to the centigrade scale.

LABORATORY EXERCISES

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"FIRST COURSE IN CHEMISTRY"

LABORATORY EXERCISES

EXERCISE 1

THE METRIC SYSTEM; THE BUNSEN BURNER

Apparatus. Graduated test tube; balance sensitive to 1 cg.; watch glass; 100-cc. beaker; Bunsen burner.

Materials. 5 or 6 g. common salt.

I. THE METRIC SYSTEM (See Appendix)

a. Length. By means of the scale (see Appendix), measure the length (in centimeters) of various pieces of apparatus included in your outfit, as a test tube, file, and blowpipe. What is the diameter of your filter paper? Finally, estimate the lengths of various objects, as a pencil, a test tube; then measure. Continue until you can approximate the lengths of small objects.

b. Volume. By means of a graduated test tube or cylinder, measure (in cubic centimeters) the volumes of various test tubes, beakers, and flasks included in your outfit. (In reading off the amount of the liquid in a graduated tube, always read from the lower part of the meniscus; that is, the curved surface of the liquid.)

c. Weight. Ask the assistant for instruction in regard to the use of the balance; then weigh various small objects, as a porcelain crucible, a watch glass. What is the approximate weight of a nickel five-cent piece?

Accurately balance a watch glass on the scalepan (using either the weights or a small pill box and fine shot) and weigh out on this exactly 5.2 g. of common salt.

Balance a small (clean and dry) beaker on the scalepan; then remove it from the pan and pour into it, as nearly as possible, 10 cc. of distilled water (measured in the graduated tube included in your laboratory outfit). Reweigh, and note the weight of the water. How do you account for the fact that it does not weigh exactly 10 g.?

II. THE BUNSEN BURNER

The Bunsen burner is a form of apparatus used for burning gas and is commonly employed in the laboratory as a source of heat. It consists of the tube *A* (Fig. 1), screwed into the base *B*. The tube has two small openings near its lower part. A small band *C*, provided with similar openings, fits around the lower part of the tube in such a way that the openings of the tube may be closed or kept open by turning the band. Gas is admitted through *D* by means of rubber tubing.

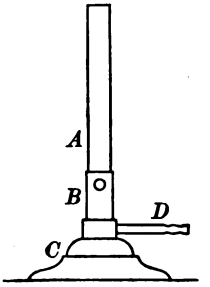


FIG. 1

Unscrew the tube and examine the different parts of the burner; then put them together again and light the gas by holding a lighted match 4 or 5 cm. above the tube and turning on the gas. The supply should be adjusted so as to give a flame about 10 cm. high. The gas flowing through the tube mixes with the air drawn in through the openings in the lower part of the tube and burns with an almost nonluminous flame. If the band is adjusted so as to close the openings, the flame becomes luminous. Always use the nonluminous flame unless otherwise directed.

EXERCISE 2

A STUDY OF SOME OF THE CHANGES TAKING PLACE WHEN A SUBSTANCE BURNS

Apparatus. Porcelain crucible; Bunsen burner; ring stand; pipe-stem triangle to support the crucible while being heated; pneumatic trough (or dish); wide-mouthed bottle or large beaker; candle.

Materials. 2 or 3 g. powdered iron; 2 or 3 g. granulated tin; pellet of phosphorus, size of a small pea (to be obtained from the instructor when needed); 5 cc. limewater (R.S.).

a. The burning of metals. Place 2 or 3 g. of powdered iron in a porcelain crucible and accurately weigh. Now heat the crucible (Fig. 2) until the iron begins to glow (burn); then withdraw the heat. Does the iron continue to burn? After the crucible is cool, reweigh. Compare the weight of the product with that of the unburned iron (?). The experiment may be repeated, using tin.

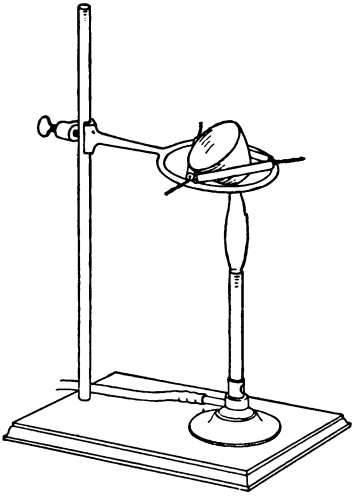


FIG. 2

b. The burning of phosphorus. (PRECAUTION. *Phosphorus must be kept and handled only under water; otherwise it may ignite, and serious results follow.*) Cover the bottom of a pneumatic trough with water to a depth of 2 or 3 cm. On the water float a porcelain crucible containing a piece of phosphorus the size of a small pea.

Ignite the phosphorus by touching it with a hot wire or the end of a hot file, and quickly invert over the crucible a large

beaker (or a wide-mouthed bottle), being careful to keep the rim of the beaker below the surface of the water. The white powder formed by the burning phosphorus floats in the air in the beaker but is gradually dissolved by the water.

Leave the beaker in position until the powder has entirely disappeared. Note that the water has risen in the beaker. How do you account for this fact? Is your conclusion in accord with the results obtained by burning iron in air? Suppose it were possible for you to collect and weigh the white powder formed by the burning phosphorus, how would you expect its weight to compare with that of the unburned phosphorus?

c. The burning of a candle. Hold a cold, dry, wide-mouthed bottle over a candle flame as shown in Fig. 3. Note the film of moisture collecting on the bottle. After one or two minutes remove the bottle quickly and pour into it 5 cc. of clear lime-water. Place the palm of the hand tightly over the mouth of the bottle and shake the contents. Note any change in the appearance of the limewater.

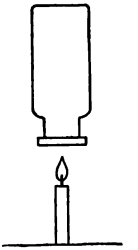


FIG. 3

Clean and dry the bottle and repeat the experiment, but omit holding the bottle over the candle flame. What conclusions do you draw from the experiment? How do you account for the fact that a burning candle gradually disappears, while iron on burning increases in weight?

[1] The page references are to McPherson and Henderson's "First Course in Chemistry."

EXERCISE 3

CHEMICAL COMPOUNDS; ELEMENTS; CHEMICAL CHANGES; CHEMICAL AFFINITY

Apparatus. Hard-glass test tube; burner; wooden splint; ordinary test tube.

Materials. 0.5 g. mercuric oxide; 2 to 3 g. sugar; bit of lime or crayon.

a. The action of heat on mercuric oxide. Introduce about 0.5 g. of mercuric oxide (ash of mercury) into a clean, dry test tube. This is done by placing the oxide near the end of a narrow strip of folded paper and introducing it carefully into the tube, as shown in Fig. 4. On inclining the tube and gently tapping the paper, the oxide will be deposited in the bottom of the tube. The paper is then withdrawn, leaving the sides of the tube perfectly clean.

FIG. 4

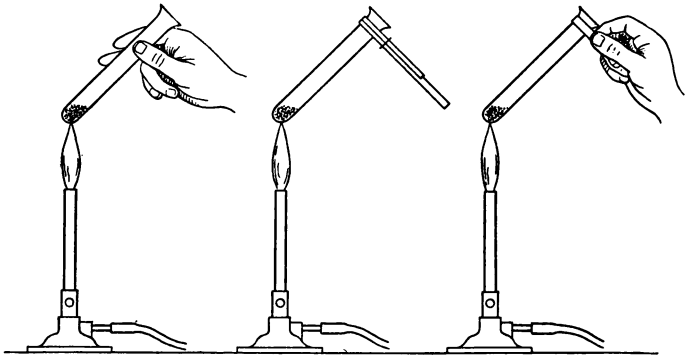


FIG. 5 FIG. 6 FIG. 7

Hold the tube between the thumb and fingers (Fig. 5) and apply a gentle heat to the oxide. The tube must be rotated constantly to distribute the heat. If the upper part of the

tube becomes hot, it may be supported by a test-tube holder (Fig. 6) or by a band of paper wrapped about the tube (Fig. 7). While the heating is continued, insert a glowing splint from time to time into the mouth of the tube. Note the result. Continue to heat as long as any gas is evolved. What is the gas (p. 5 of text)? What remains in the tube? How has the heat affected the mercuric oxide?

What name is applied to substances which, like mercuric oxide, can be decomposed into two (or more) simpler substances differing from the original substances in properties?

Define the following terms, illustrating each by reference to the experiment (pp. 8, 9 of text): (*a*) chemical compound; (*b*) element; (*c*) chemical change; (*d*) chemical affinity.

b. *The action of heat upon sugar.* Introduce 2 or 3 g. of sugar into a test tube and heat (as in ***a*** above) until no further change takes place. The residue is the element carbon. Describe your results, illustrating the meanings of the terms *chemical compound*, *element*, and *chemical change.*

c. *The action of heat upon lime.* Try the effect of heat upon a bit of lime or crayon. Discuss the results of the experiment with your instructor before attempting to draw any conclusions.

EXERCISE 4

THE MANIPULATION OF GLASS TUBING

Apparatus. Burner and wing-top attachment; hard-glass test tube with cork to fit; cork-borers; triangular file; round file.

Materials. Glass tubing (soft), external diameter 6 mm.; about 30 cm. of glass rod.

a. *To fit a tube with stopper and glass tube as shown in Fig. 8.* In all operations requiring the application of a strong heat to glass, the heat must be applied gently at first. Highly heated glass must be cooled slowly; otherwise it is easily broken.

Cut from one of the lengths of soft-glass tubing a piece about 15 cm. in length. To do this, place the tubing on the

desk and draw the edge of a triangular file across the point at which you wish to cut the glass. After the glass has been scratched, take the tube in the hands with the thumbs placed near together just back of the scratch (Fig. 9), and gently pull the glass apart, at the same time exerting a slight pressure with the thumbs. If the tube does not yield readily to a gentle pressure, a deeper scratch must be made. In the case of large tubing it may be found necessary to file a groove around the glass. The edges of the cut tube will be sharp, and should be rounded by being rotated in the tip of the Bunsen flame.

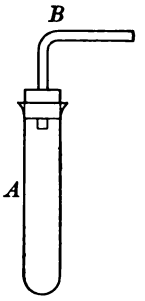


FIG. 8

To bend the glass tubing, first heat it at the point where you wish to bend it, in the luminous Bunsen flame spread out by means of the so-called " wing-top " burner (Fig. 10). Hold the tube lengthwise in the flame, gently rotating it so that all sides may be equally heated. Continue the heating until the glass bends easily, then remove it from the flame and quickly bend it to a right angle *B* (Fig. 8). Great care must be taken

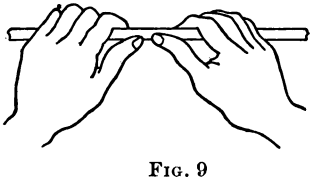


FIG. 9

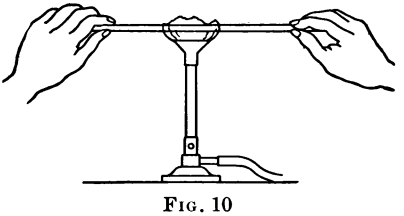


FIG. 10

to heat the tube uniformly, otherwise the bore of the tube will be contracted (*A*, *B*, Fig. 11), forming a bend which is not only unsightly but easily broken.

Next select a cork of such a size that the smaller end will just enter the hard-glass test tube. Soften the cork by rolling it between the desk and a block of wood. Now insert into the cork the glass tube prepared as directed above. To do

this, select a borer slightly smaller than the tube. Place the cork on the desk and cut half through it with the borer, not by punching but by rotating the borer under gentle pressure (Fig. 12); then reverse the cork and bore through from the other end. Care must be taken to keep the borer at a right angle to the top and base of the cork. The hole should be straight and smooth.

The glass tube, rounded at the edges, is now inserted in the cork by a gentle, screwlike motion. If the hole is too small to

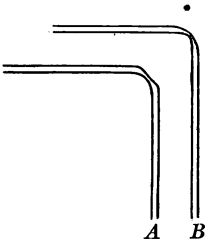


FIG. 11

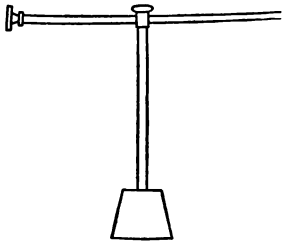


FIG. 12

admit the tube when a gentle pressure is applied, it may be slightly enlarged with a round file. Now put the cork in the test tube and set the apparatus aside for use in preparing oxygen (Exercise 6).

If time permits, the pupils may also construct the apparatus (Fig. 18, Exercise 8) used in preparing hydrogen.

b. *To make glass stirring-rods.* These should be about 15 cm. in length. Round the ends by heating in the Bunsen flame. Place the finished rods in the desk for future use.

EXERCISE 5

THE COLLECTION OF GASES; THE PREPARATION OF OXYGEN

Apparatus. Three 250-cc. wide-mouthed bottles; 3 pieces of glass (window) 10 cm. square; pneumatic trough; rubber tubing; burner; 2 test tubes.

Materials. 4 g. potassium chlorate; 1 g. manganese dioxide; wooden splints.

a. *Collection of gases.* Fill a 250-cc. wide-mouthed bottle with water. Cover its mouth with a glass plate, being careful to exclude all air bubbles. Hold the plate firmly in place, invert the bottle, and dip its mouth into the water in a pneumatic trough. Remove the glass plate. Why does the water remain in the bottle? Now, without changing the position of the bottle, fill it with exhaled air by placing one end of a piece of glass or rubber tubing under the mouth of the bottle and blowing gently through the other end.

Before the bottle, so filled, is removed from the trough, cover its mouth tightly with a glass plate. The bottle so covered may then be placed on the desk either right side up or in an inverted position. (When should it be placed in an inverted position?)

Fill a bottle with exhaled air and then transfer the air to another bottle. Draw a diagram to show the method of doing this.

b. *Preparation of oxygen from mercuric oxide.* Recall Exercise 3, Experiment ***a.***

c. *Preparation of oxygen from potassium chlorate (preliminary experiment).* Select two test tubes of the same size, and clean and dry them thoroughly. Into the one introduce 2 g. of potassium chlorate; into the other introduce 2 g. of potassium chlorate mixed intimately with 1 g. of manganese dioxide.

Now heat the contents of the two tubes, applying the flame so that both tubes are equally heated. Repeatedly thrust a glowing splint into each tube in order to detect any oxygen that may be evolved. Note the results. What effect has the manganese dioxide? From which tube is the greater amount of oxygen evolved (p. 16 of text)?

EXERCISE 6

THE PREPARATION AND PROPERTIES OF OXYGEN

Apparatus. Hard-glass test tube fitted with cork and delivery tube as shown in Fig. 13 (use apparatus constructed in Exercise 4); four 250-cc. wide-mouthed bottles; 4 pieces of glass 10 cm. square; pneumatic trough; ring stand and burner; deflagrating-spoon.

Materials. 6 g. potassium chlorate; 3 g. manganese dioxide; wooden splints; bit of sulfur; picture-frame wire 20 cm. long; bit of cotton.

a. Usual laboratory method for preparing oxygen. Mix intimately on paper 6 g. of potassium chlorate and 3 g. of manganese dioxide. The presence of impurities in the materials may lead to a serious explosion when heat is applied; hence test a small portion of the mixture, say 0.5 g., by heating it in a test tube. In the absence of impurities the oxygen is evolved quietly, unaccompanied by any very marked sparking in the materials.

If pure, transfer the remainder of the mixture to a hard-glass tube and insert the cork (Fig. 13); then, holding the burner in the hand, heat the mixture gently with a small flame, applying the heat at first to the upper part of the mixture. The flame must not strike the upper part of the test tube, as the cork may be ignited. At first the heat expands the air and a few bubbles of air escape; then the oxygen is evolved. Regulate the heat so as to secure a uniform and not too rapid evolution of the gas. Collect three or four 250-cc. wide-mouthed bottles of the gas. Before the heat is withdrawn, remove the cork from the tube (?). What is the

source of the oxygen? What is the function of the manganese dioxide? Place the tube and contents aside for use in Exercise 7.

b. Note the physical properties (color, odor, taste, solubility in water) of the gas. (The slight cloud that is often present when oxygen is prepared from potassium chlorate is due to an impurity and will disappear if the gas is allowed to stand over water.)

c. Repeatedly thrust a glowing splint into a bottle of the gas.

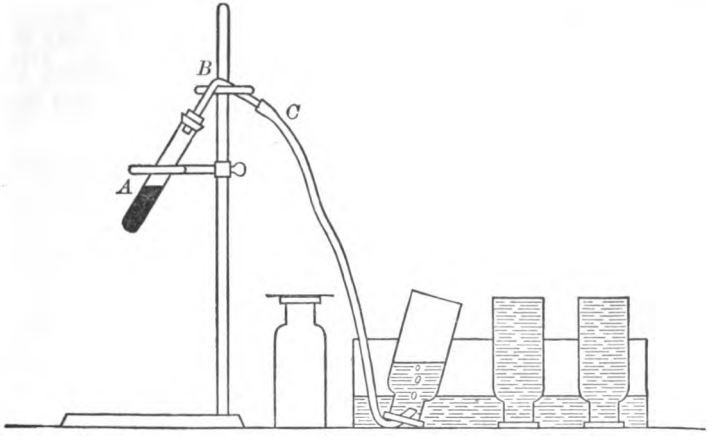


FIG. 13

d. Heat some sulfur in a deflagrating-spoon until it begins to burn. Note the color and size of the sulfur flame. Now lower the burning sulfur into a bottle of oxygen and note the change.

e. Tip the piece of picture-frame wire with sulfur by wrapping a very small bit of cotton about the end of the wire and dipping this into melted sulfur (for this purpose melt a little sulfur in a deflagrating-spoon). Ignite the sulfur by holding it in a Bunsen flame for an instant, and then thrust the wire into a bottle of oxygen.

Describe the results obtained in *c*, *d*, and *e*. What becomes of the oxygen?

EXERCISE 7

SOME FURTHER PRELIMINARY MANIPULATIONS

Apparatus. 2 beakers; glass rod; filter paper, funnel, and ring stand; evaporating-dish; burner.

Materials. Substances left in the preparation of oxygen (Exercise 6).

a. *Pouring liquids from one vessel to another.* In doing this care must be taken to prevent the liquid from running down the side of the vessel from which it is poured. A glass rod (prepared in Exercise 4) should be held lightly against the rim of the vessel, as shown in Fig. 16. The liquid will flow down the rod.

Fill a beaker with water and transfer it slowly to another vessel without using the glass rod; repeat, using the glass rod.

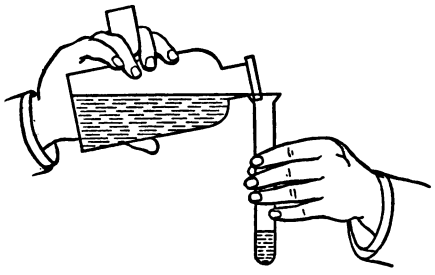


FIG. 14

FIG. 15

In pouring liquids from bottles a glass rod may be used or the neck of the bottle may be placed lightly against the rim of the vessel into which the liquid is being poured (Fig. 14). This will prevent the liquid from running down the side of the bottle. The stopper must never be laid on the desk. Catch it between the fingers, as shown in Fig. 15, leaving the hand free to grasp the bottle, as shown in Fig. 14.

b. Decantation; filtration. It is often necessary to separate a liquid from a finely divided solid which is suspended in it. This may be done by one of the two following methods:

When the solid is heavy and readily settles to the bottom of the vessel, the liquid may be carefully poured off, or *decanted.* Sand suspended in water may be separated from the liquid in this way.

Usually, however, the solid will not readily settle or will do so only after long standing. In such cases the mixture is *filtered,* by pouring it on a filter paper, which allows the liquid to run through but retains the solid. To prepare the filter paper, fold it along a diameter into halves, then, at right angles to the first fold, into quarters. The folded filter is then opened so as to form a cone, half of which is composed of three thicknesses of paper, and the remainder of one thickness. Now fit the cone into a funnel of such a size that the paper does not quite reach the top. The paper must accurately fit the funnel; if it does not, make it do so by varying the fold. Place the paper in the funnel and thoroughly wet it with water. After the water has run through, press the paper firmly against the sides of the funnel with the finger so as to remove any air bubbles between the paper and the glass. The filter is now ready for use (Fig. 16). The process of filtration not only enables us to separate liquids from solids but also certain solids from each other, as is illustrated in the following experiment.

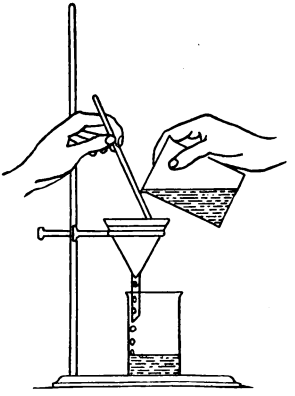


FIG. 16

**c. Separation of the compounds present in the residue left in the preparation of oxygen.* Heat the tube containing the residue left in the preparation of oxygen (Exercise 6) until no

more oxygen is evolved. After the tube is cool, nearly fill it with water and shake the contents thoroughly. Pour the mixture into a small beaker and add 10 cc. more of water. Now heat the mixture gently, stirring it in the meanwhile with a glass rod so that any soluble substance present may be dissolved in the water. After a few minutes, filter off the solid matter (Fig. 16), repeating the filtration, if necessary, in order that the liquid passing through the filter paper (this liquid is known as the *filtrate*) may be perfectly clear.

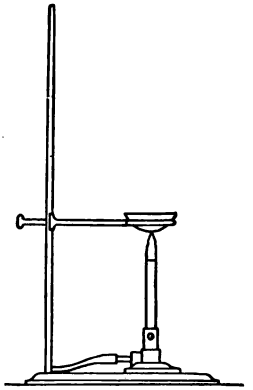


FIG. 17

Next evaporate the filtrate. To do this, pour the filtrate into an evaporating-dish, support the dish on a ring stand (Fig. 17), and heat gently. The liquid may be made to simmer, but should not actually boil (?). Withdraw the heat as soon as the water is evaporated. Note the residue left. Convince yourself that it is different from the potassium chlorate used in the preparation of oxygen (p. 16 of text). What substance is left on the filter paper? Could any two solids be separated by this process?

EXERCISE 8

THE PREPARATION AND PROPERTIES OF HYDROGEN

Apparatus. Test tube; apparatus, bottles, and trough as shown in Fig. 18 (the bottles are 250-cc., wide-mouthed); beaker; stirring-rod; 60-cc. bottle; burner; evaporating-dish.

Materials. Bit of sodium (size of a small pea); filter paper; wooden splints; 10 g. granulated zinc; copper sulfate solution (R. S.); sulfuric acid.

a. *Preparation from water.* Fill a test tube with water and invert it in a beaker of water. Wrap a piece of sodium in a

bit of filter paper previously moistened with coal oil. Raise the inverted test tube until its mouth dips just below the surface of the water in the beaker, and quickly insert the sodium. Stand at arm's length, as a slight explosion sometimes occurs. Notice that the sodium decomposes the water, liberating a gas which is caught in the tube. Place your thumb tightly over the mouth of the tube to prevent the gas from escaping, and bring the tube to an upright position. Light a splint, remove the thumb from the tube, and quickly bring the flame to the mouth of the tube. Does the gas act like

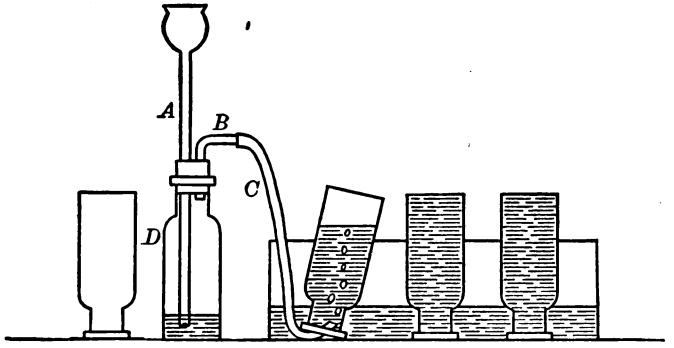


FIG. 18

oxygen? What is the source of the gas? What other methods may be employed for obtaining it from the same source?

b. Preparation from acids (usual laboratory method). Prepare a hydrogen generator according to Fig. 18. *D* represents a wide-mouthed bottle of about 250-cc. capacity. The gas-delivery tube *B*, *C* is the same as that used in the preparation of oxygen (Fig. 13). A rubber stopper for the bottle *D* is preferable, although a good cork stopper will do. The funnel tube *A* must extend nearly to the bottom of the bottle (?). Put 10 g. of granulated zinc (why granulated?) into *D*, and add a few drops of a solution of copper sulfate. Now pour just enough water through the funnel tube to cover the zinc.

Prove that the apparatus is air-tight by blowing into the delivery tube *C* until the water is forced nearly to the top of the funnel tube; then quickly close the rubber tube either by tightly pinching it or by placing the tongue firmly against its end. If the apparatus is air-tight, the water in the funnel tube will not fall.

Prepare some dilute sulfuric acid by *slowly* pouring 15 cc. of concentrated acid into a beaker containing 50 cc. of water. Stir the water with a glass rod while the acid is being added. *Notice that the acid is poured into the water — never the reverse.*

Cool the mixture and pour a few drops of it through the funnel tube. Hydrogen is at once evolved. Enough of the acid must be added from time to time to cause a gentle and continuous evolution of the gas. An excess of the acid should be avoided, however, or the action will become too violent and a large quantity of zinc will have to be added at the close of the exercise.

It is evident that the gas which passes over first is a mixture of hydrogen and air. *The student must remember that such a confined mixture of hydrogen and air explodes with great violence if ignited.* Hence see that the end of the delivery tube is not brought near any flame. Determine when the hydrogen is free from air by repeatedly collecting a test tube full of gas and igniting it, holding the tube mouth downward (?). If pure, the gas burns quietly; otherwise there is a slight explosion. After all the air has been expelled from the generator, collect four bottles (250-cc., wide-mouthed) of the gas.

What is the source of the hydrogen? What is the use of the zinc? Why is the copper sulfate solution added (p. 28 of text)?

Remove the cork from the generator, add a few more pieces of zinc, and set aside. Sufficient zinc should be used so that at least a small portion of it remains undissolved.

c. Thrust a lighted splint into a bottle of the gas held mouth downward. Slowly withdraw the splint and again thrust it into the gas. Describe the results. What do they prove?

d. Fill a small (60-cc.) wide-mouthed bottle or test tube one-third full of water and invert it in a pneumatic trough. Displace the remaining water with hydrogen from one of the bottles. What does the bottle now contain? Withdraw it from the water and, holding it at arm's length, quickly bring it, mouth downward, over a flame. What do the results prove?

e. Uncover a bottle (mouth upward) of the gas. After a minute, test for the presence of hydrogen with a lighted splint. Repeat, holding the bottle mouth downward. Describe the results. Is the gas heavier or lighter than air?

**f.* Without removing the fragments of undissolved zinc, pour the liquid set aside in Experiment *b* into an evaporating-dish and boil gently on a ring-stand support. As soon as white crusts begin to form on the side of the dish, just above the liquid, filter the hot liquid into a beaker and set it aside to cool. How does the product which separates from the filtrate compare in properties with the original zinc? Has the zinc undergone any change? Explain (p. 27 of text).

EXERCISE 9

THE COMBUSTION OF HYDROGEN; THE OXYHYDROGEN BLOWPIPE

Apparatus. Hydrogen generator *A* (Fig. 19) attached by rubber tubing *C* to a drying-tube *B*. This tube is filled with granulated calcium chloride, held in place by loose plugs of cotton placed at each end of the tube. *D* is a glass tube drawn to a jet.

Materials. Granulated calcium chloride; cotton; 8 g. zinc; 2 or 3 drops copper sulfate solution (R.S.); dilute sulfuric acid; picture-frame wire 10 cm. long; bit of charcoal.

a. Charge the generator *A* (Fig. 19) with 6 or 8 g. of zinc, add the solution of copper sulfate, cover with water, and add

dilute sulfuric acid as in *b*, Exercise 8. Slip a piece of rubber tubing over the tube *D*, collect samples of the gas in test tubes over water, and test with a flame to see whether the hydrogen is free from air. *After all the air has been expelled, wrap a towel carefully about the generator* and cautiously ignite the hydrogen. The flame is nearly invisible and is very hot. Test the heat of the flame by holding in it different objects, such as a splint, a piece of picture-frame wire, a bit of charcoal.

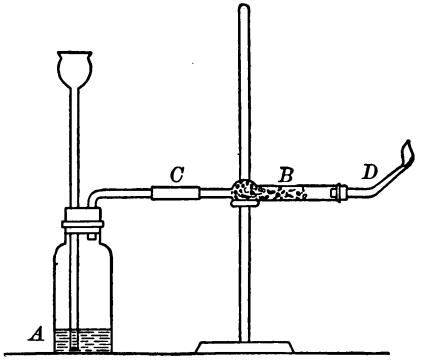


FIG. 19

Finally, hold over the flame a cold, dry beaker or bottle and note the liquid deposited on the sides of the vessel. Explain.

b. Examine the structure of the oxyhydrogen blowpipe. Draw a diagram representing a cross section of it.

EXERCISE 10

MEASUREMENT OF GAS VOLUMES (OPTIONAL)

Apparatus. Graduated tube and cylinder, as shown in Fig. 20; thermometer.

a. (It is suggested that the instructor arrange one or more pieces of apparatus as shown in Fig. 20. The students will then take the readings and solve the problems.)

Partially fill a graduated tube with water and invert it in a cylinder (or other vessel) of water as shown in Fig. 20. Adjust the tube until the level of the liquid inside and outside of the tube is the same; then take the reading of the

volume of the air in the tube. Note the temperature of the air (place a thermometer by the side of the tube) and likewise the pressure of the atmosphere as indicated by the barometer. Insert these values in their appropriate places in the following table:

Volume of air in tube	cc.
Temperature of air	°
Vapor pressure at temperature of air (see Appendix)	mm.
Barometric pressure	mm.
Effective pressure on gas in tube (barometric pressure less vapor pressure)	mm.

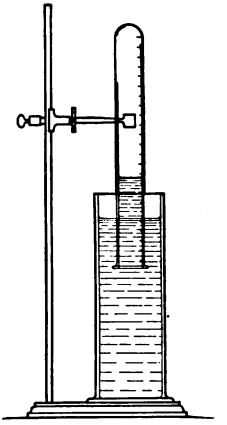


FIG. 20

From the above values, calculate what volume the air inclosed in the tube would have under standard conditions.

b. If time permits, the remainder of the laboratory period may be spent in solving the problems at end of Chapter V.

EXERCISE 11

A STUDY OF THE PROCESS OF DISTILLATION

Apparatus. Flask (250-cc.); condenser and connections as shown in Fig. 21, or apparatus shown in Fig. 22; ring stands; wire gauze 12 cm. square; watch glass.

Materials. 10 cc. alcohol.

a. (Two or more students may work together if the apparatus is not available for each.) Connect a Liebig condenser *B* with a 250-cc. flask *A*, as represented in Fig. 21. The flask is set on a piece of wire gauze supported by the iron ring attached to the ring stand. The tube *C* is connected with the water pipe by means of rubber tubing, and a current of cold water is conducted through the outer tube of the condenser. (Why is cold water forced in at *C* rather than at *D*?)

Fill the flask one-fourth full of hydrant or well water and boil until 50 cc. or more of liquid has collected in the *receiver E.* (In case condensers are not available, the apparatus shown in Fig. 22 may be used. When this is used the steam from the boiling water in flask *A* is condensed by conducting it through *B* into the test tube *C* which is kept cold by the ice water in the beaker *D.*)

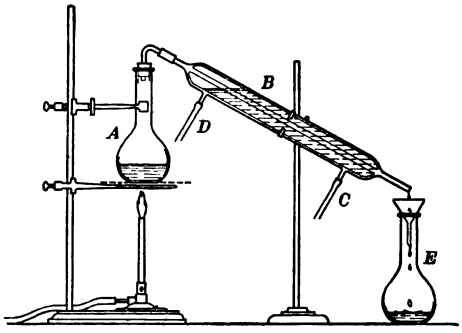


FIG. 21

Compare the *distillate* (distilled water) with the hydrant water in appearance and in taste (?).

Place 4 or 5 drops of the distilled water on a watch glass and evaporate, holding the watch glass 10 or 15 cm. above the tip of the flame. Is there any residue? Repeat, using hydrant water. Why is distilled water used in the laboratory?

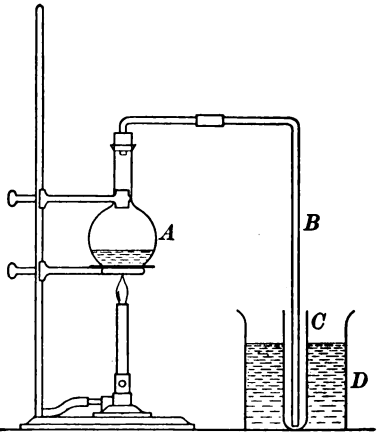


FIG. 22

b. Repeat the distillation, using a sample of muddy water in *A* (?).

c. Distill a mixture of 10 cc. of alcohol (boiling point 78.3°) and 30 cc. of water. Collect the first 1 or 2 cc. of the distillate in an evaporating dish and test with a flame. In the same way test successive portions of the distillate. Does there seem to

be a partial separation of the two liquids? In this way a mixture of liquids boiling at different temperatures may generally be separated more or less perfectly. The process is termed *fractional distillation.*

EXERCISE 12

THE QUALITATIVE SYNTHESIS OF WATER; OXIDATION AND REDUCTION

Apparatus. Hydrogen generator and tubes as shown in Fig. 23 (*A* is the hydrogen generator, *B* is a drying-tube filled with calcium chloride, *C* is a straight glass tube, and *D* is a hard-glass test tube); burner; apparatus used in preparing oxygen (Fig. 13).

Materials. 2 g. copper oxide; calcium chloride sufficient to fill the drying-tube *B*; 8 g. zinc; dilute sulfuric acid for preparing hydrogen (see Exercise 8); 4 g. potassium chlorate; 2 g. manganese dioxide.

a. Recall *a*, Exercise 9. The experiment proves the presence of what elements in water?

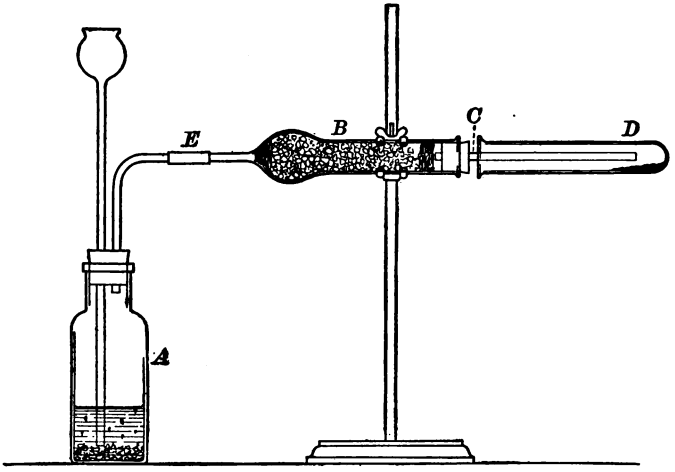


FIG. 23

b. Remove the tube *D* (Fig. 23), introduce into it 1 or 2 g. of copper oxide, and return it to the position shown in the figure.

Now generate hydrogen in *A* as in Exercise 8. After all the air has been expelled from the apparatus and the generator wrapped in a towel (see Exercise 9) cautiously heat the copper oxide to redness, being careful to keep the flame away from the mouth of the tube *D* (?). Note the condensation of moisture in the cold portions of the tube. Is there any invisible evidence of change in the copper oxide? Explain.

c. Disconnect the bottle *A* at *E* from the rest of the apparatus and force a little air through the tube *B* to remove the hydrogen present. Now connect the apparatus used in preparation of oxygen (Fig. 13) at *E* to the tubes *B*, *C*, and *D*. Generate oxygen and conduct a slow current of the gas through *B*, *C*, and *D*, at the same time heating the residue in *D* (?).

d. Explain the terms *reduction* and *oxidation* and give an example of each process from the above experiment.

EXERCISE 13

THE PROPERTIES OF HYDROGEN PEROXIDE

Apparatus. 3 test tubes; funnel.

Materials. 10 cc. hydrogen peroxide solution; 1 g. manganese dioxide; wooden splint; black hair; filter paper.

a. What is the strength of the hydrogen peroxide solution sold by druggists (p. 52 of text)? Pour 3 cc. of the solution into a large test tube and add 1 or 2 g. of finely powdered manganese dioxide. Test the glass evolved with a glowing splint (?).

Filter the mixture remaining in the tube. The solid is the unchanged manganese dioxide. In what other experiment has manganese dioxide brought about a change without apparently undergoing any change itself?

b. Immerse some black hairs for a few seconds in a solution of the peroxide; remove the hairs, place them on a piece of paper, and examine them at the close of the laboratory period.

c. If time permits, the student is advised to prepare the apparatus shown in Fig. 26, Exercise 15, and set it aside for use when that exercise is reached.

EXERCISE 14

BOILING POINTS AND FREEZING POINTS

Apparatus. Flask (250-cc.) fitted with a two-hole cork, through which pass the thermometer *B* and the glass tube *C*, as shown in Fig. 24; test tube; large beaker; small beaker; ring stand; burner.

Materials. 300 g. ice; 100 g. common salt.

a. Boiling points. Fill the flask *A* (Fig. 24) about one-third full of water. Lower the thermometer until the bulb is immersed in the liquid. Heat the water to boiling and note the temperature after it has become constant. Apply a greater heat and note the effect upon the temperature.

Raise the thermometer until the bulb no longer touches the boiling water but is simply exposed to the steam. Again note the temperature. Note your general conclusions.

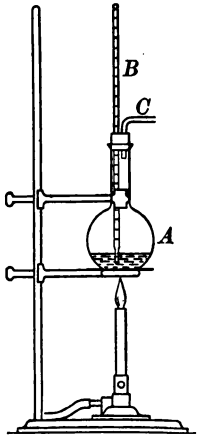


FIG. 24

b. Freezing points. Place some pieces of ice in a small beaker. Introduce 15 or 20 cc. of water and stir the mixture gently with the bulb of the thermometer. Continue until the temperature is constant (?).

Half fill a test tube with pure water and dip the tube into a freezing-mixture made by mixing 3 parts of powdered ice with 1 part of common salt. Stir the water in the test tube from time to time with a thermometer and note the temperature at which it begins to freeze. Compare the freezing point of water with the melting point of ice.

EXERCISE 15

THE DETERMINATION OF THE WEIGHT OF ONE LITER OF OXYGEN; ALSO THE DETERMINATION OF THE PERCENTAGE OF OXYGEN IN POTASSIUM CHLORATE (QUANTITATIVE) (OPTIONAL)

Apparatus. Apparatus shown in Fig. 25; burner; 500-cc. beaker.
Materials. 1 g. potassium chlorate.

a. (While this exercise is marked optional, the student is strongly recommended to perform the experiment. The apparatus is simple and may be used for a number of experiments. Two students may work together.)

Prepare the form of apparatus shown in Fig. 25. *A* represents the hard-glass test tube used in the preparation of oxygen, *B* is a common (narrow-mouthed) bottle, having a capacity of about 1 liter; rubber stoppers should be used in both *A* and *B*. The rubber tube *C* is provided with a screw clamp *D*, for closing the tube, and has in its end a glass tube *E*. The end of this glass tube is drawn out to a jet, the internal diameter of the jet being about 2 mm. *F* is a 500-cc. beaker.

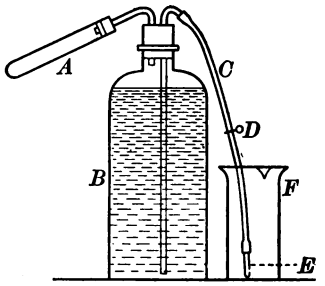


FIG. 25

The bottle is nearly filled with water, as shown in the figure, and allowed to stand until it acquires the room temperature. The tube *A* is now removed and a gentle suction is applied to the glass jet *E*. The water siphons over, through the tube *C*, into the beaker and is allowed to run for a moment so as to fill completely both the rubber and the glass tubes (*C* and *E*). The rubber tube is then quickly closed with the screw clamp *D*.

Now thoroughly clean and dry the tube *A* and carefully weigh it; then introduce about 1 g. of potassium chlorate into the bottom of the tube, by means of a folded paper (Fig. 4), and reweigh. Attach the tube, as shown in Fig. 25, *care being taken to have the apparatus air-tight.*

The pressure of the air within the bottle is now adjusted to that of the air outside as follows: Water is added to the beaker *F*, if necessary, until the end of the glass tube *E* is covered. The screw clamp is then opened and the beaker at once raised vertically until the water in the beaker is at the same level as the water in the bottle and is retained in this position until the screw clamp *D* is closed. The beaker is then emptied and returned to the position shown in Fig. 25.

Now open the screw clamp and apply a gentle heat to the potassium chlorate in *A*. The oxygen is evolved and forces the water from the bottle into the beaker. Gradually increase the heat, and *continue the heating until all the oxygen has been expelled* (shown by the fact that no more water passes over into *F*). Let the apparatus stand until it has acquired the room temperature, care being taken that the glass jet *E* is kept below the surface of the water in the beaker (?).

Now bring the level of the water in the beaker to that of the water left in the bottle, and while holding it in this position, close the screw clamp (?). Carefully measure the water in the beaker; also take the reading of the thermometer and the barometer. Disconnect the tube *A* and carefully reweigh. Insert the values in the following table:

Weight of tube *A*	g.
Weight of tube *A* + potassium chlorate	g.
Weight of tube *A* + potassium chloride	g.
Weight of oxygen evolved (loss in weight of contents of tube *A* on heating)	g.
Volume of water in beaker = volume of oxygen evolved	cc.
Temperature of water	°
Barometric reading	mm.
Value of vapor pressure (see Appendix)	mm.

From your results calculate the weight of 1 liter of oxygen under standard conditions; also calculate the percentage of oxygen in potassium chlorate. Compare your results with the theoretical values (pp. 15 and 19 of text).

b. An additional laboratory period may be given to the solution of problems on page 79 of text.

EXERCISE 16

THE DETERMINATION OF THE AMOUNT OF HYDROGEN DISPLACED BY A DEFINITE WEIGHT OF DIFFERENT METALS (QUANTITATIVE) (OPTIONAL)

Apparatus. Apparatus shown in Fig. 26 (the bottle *B* and fittings are the same as used in Exercise 15 (Fig. 25)).

Materials. About 1 g. granulated zinc or aluminium; dilute sulfuric acid prepared by adding 10 cc. concentrated acid to 30 cc. water; dilute hydrochloric acid prepared by adding 20 cc. of the concentrated acid to 20 cc. water.

(Two students work together. Some should use sulfuric acid as the solvent and others hydrochloric acid, so that the results may be compared. The apparatus is not difficult to prepare and gives excellent results.)

Arrange an apparatus in accordance with Fig. 26. *A* is a 60-cc. wide-mouthed bottle. The bottle *B* and accompanying tubes are the same as shown in Fig. 25 except that the hard-glass test tube has been removed. The glass tube *G* is drawn out to a jet at the lower end, and the other end is connected to the funnel *H* by means of a

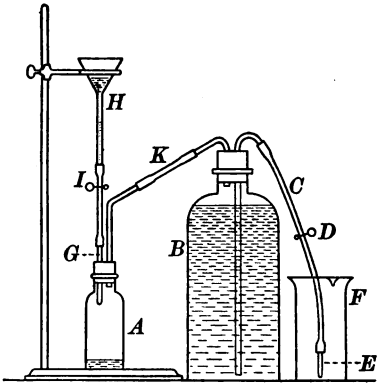


FIG. 26

rubber tube which can be closed by the screw clamp *I*. The bottles *A* and *B* are joined by a rubber tube *K*.

Disconnect the bottles *A* and *B* at *K* and fill the bottle *B* and the exit tube *C*, *E* with water, as in Exercise 15, and tightly close the screw clamp *D*.

Weigh out accurately about 1 g. of zinc. Wind a piece of platinum wire (used in place of copper sulfate solution) about the zinc, place it in the bottle *A*, and set the bottle aside.

Close the screw clamp *I* and nearly fill the funnel with the dilute sulfuric acid. Place a beaker under the tube *G* and open the screw clamp *I* until the rubber and the glass tubes are both completely filled with the dilute acid; then quickly close the clamp. Next, connect the apparatus just as shown in the figure, *taking care to make the apparatus air-tight.*

Now adjust the pressure of the air inside the bottles to atmospheric pressure, just as directed in Exercise 15.

Next, open the clamp *D*, then partially open the clamp *I* and allow 8 or 10 drops of the acid to flow into the bottle *A*. The hydrogen evolved forces the water from bottle *B* into the beaker. If necessary, more acid is added from time to time until the zinc is dissolved. After the zinc has all dissolved and the apparatus has acquired the room temperature, again adjust the pressure of the gas within the bottles to the atmospheric pressure and close the clamps *D* and *I*.

Insert the values in the table below:

Weight of metal taken	g.
Volume of water forced into the beaker	cc.
Volume of liquid left in bottle *A*	cc.
Volume of hydrogen liberated = volume of water in *F* less volume of liquid in *A*	cc.
Temperature	°
Barometric reading	mm.
Value of vapor pressure (Appendix)	mm.
Volume that the hydrogen would occupy under standard conditions	cc.
Weight of this volume of hydrogen (1 liter H = .089879)	g.

Compare the results obtained by the students using sulfuric acid as the solvent with the results obtained by using hydrochloric acid as the solvent (?). Also compare the actual results with the theoretical results.

The experiment may be repeated, using aluminium and hydrochloric acid.

EXERCISE 17

PREPARATION AND PROPERTIES OF NITROGEN

Apparatus. 250-cc. flask, with cork and glass delivery tube, like that used in preparing oxygen (*B, C,* Fig. 13); ring stand; burner; pneumatic trough; 3 wide-mouthed bottles.

Materials. 3 g. ammonium chloride; 6 g. sodium nitrite.

In a 250-cc. flask place a mixture of 3 g. of ammonium chloride and 6 g. of sodium nitrite, and add 20 cc. of water. Provide the flask with a one-hole cork and delivery tube so that the evolved gas may be collected over water, as in the case of oxygen and hydrogen. Have at hand a vessel of cold water so that the flask may be cooled by lowering it into the water in case the action becomes too violent.

Clamp the flask and apply a *very gentle* heat, moving the burner about with the hand. As soon as the action begins, withdraw the heat. After the air has been expelled from the apparatus, fill two or three bottles (250-cc.) with the gas. If the action becomes too violent, immerse the flask in cold water.

The reaction which takes place is expressed in the following equation:

$$NH_4Cl + NaNO_2 \longrightarrow NH_4NO_2 + NaCl$$

The ammonium nitrite then decomposes into water and nitrogen (R).

Note the physical properties of the gas. Will it burn?

EXERCISE 18

THE COMPOSITION OF AIR

Apparatus. Apparatus shown in Fig. 27.

Materials. 5 g. potassium hydroxide dissolved in 5 cc. water and cooled to room temperature; 4 g. pyrogallic acid dissolved in 10 cc. water; bit of calcium chloride; 10 cc. limewater (R. S.).

I. DETERMINATION OF THE RELATIVE AMOUNTS OF NITROGEN AND OXYGEN IN THE AIR (QUANTITATIVE)

The relative volumes of oxygen and nitrogen in the air may be determined by bringing in contact with a definite volume of air a liquid which absorbs the oxygen and in so doing flows into the tube which contains the air, and fills a space equal to that previously occupied by the oxygen. The volume of this liquid can be easily measured and the volume of the absorbed oxygen ascertained.

The solution used to absorb the oxygen soon loses its strength on exposure to air; the experiment must therefore be performed rapidly. Before preparing the solution the student should practice the manipulations involved in the experiment.

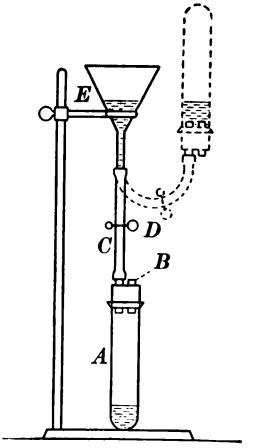


FIG. 27

Arrange an apparatus like that shown in Fig. 27. *A* represents a test tube about 15 cm. in length (use the hard-glass tube employed in the preparation of oxygen). The tube is fitted with a two-hole rubber stopper. One hole is closed with a glass rod *B*, while the other is fitted with a small glass tube, the upper end of which extends 4 or 5 cm. above the

stopper. A piece of soft-rubber tubing *C*, 12 or 15 cm. in length, connects the glass tube with a small funnel, as shown in the figure.

Close the rubber tube tightly with the screw clamp *D*. Disconnect the test tube and remove the glass rod *B* from the stopper preparatory to performing the experiment.

Add the solution of potassium hydroxide to the solution of pyrogallic acid, mix, and *at once* pour the resulting liquid into the funnel *E*. Quickly open the screw clamp *D* until the rubber tube and the glass tube are both filled with the liquid, and then close the clamp tightly.

Connect the test tube, holding it by the rim to avoid heating the contained air, and insert the glass rod in the cork. The air inclosed in the tube is now at the same temperature and pressure as the surrounding air.

Now open the screw clamp. The liquid flows in, absorbing the oxygen. When the liquid ceases to enter, grasp the tube by the rim and invert it, as shown by the dotted lines of the figure, adjusting it so that the level of the liquid is the same in both tube and funnel (?); then clamp the rubber tube tightly and return the test tube to its original position.

Mark the volume of the air originally inclosed in the tube by placing a narrow strip of gummed paper about the tube at the lower end of the stopper; mark also, by a strip of paper placed at the level of the liquid in the tube, the volume of the oxygen absorbed.

Disconnect the tube and rinse it. Measure the volume of the tube to each strip of paper by pouring in water from a graduated cylinder. From these measurements calculate the number of volumes of oxygen and nitrogen in 100 volumes of air.

NOTE. This experiment disregards the presence in the air of all constituents other than oxygen and nitrogen. The volume of such constituents, however, in the amount of air taken is smaller than the unavoidable errors in the experiment.

a. Place a piece of calcium chloride on a watch glass and expose it to the air for two or more hours. What do the results indicate? (A substance which, like calcium chloride, takes up moisture on exposure to air is said to be *deliquescent.*)

b. Expose a few cubic centimeters of limewater to the air for a half hour. The formation of a white crust on the limewater proves the presence of carbon dioxide in the air (see p. 201 of text).

EXERCISE 19

A STUDY OF SOLUTIONS

Apparatus. 5 test tubes; watch glass; funnel; apparatus shown in Fig. 24, Exercise 14.

Materials. 2 g. sugar; 5 cc. alcohol; 0.2 g. calcium sulfate; 2 crystals of potassium permanganate; bit of soap size of a bean; 1 cc. cottonseed oil or kerosene; 25 g. common salt; filter paper; 3 g. potassium nitrate.

a. Place 1 g. of sugar in each of two test tubes. To the one test tube add 5 cc. of water and to the other 5 cc. of alcohol. Shake the contents thoroughly (?).

b. Place about 0.2 g. of calcium sulfate in a test tube and add 5 cc. of water. Shake the mixture thoroughly for a few seconds; then set the tube aside for five or ten minutes. Filter a few drops of the liquid, collecting the filtrate on a watch glass. Set the glass on a small beaker partially filled with boiling water (Fig. 31) until the filtrate is evaporated (?).

c. Nearly fill two test tubes with water and set them in a rack. Drop into each a small crystal of potassium permanganate. Shake the contents of one tube and repeat the shaking after a few minutes. At the close of the laboratory period note the appearance of the liquid in each tube (?).

d. Select two tubes, filling the one nearly full of distilled (or soft) water and the other with a like amount of distilled water in which a small bit of soap has been dissolved. Add

to each tube 3 or 4 drops of cottonseed oil or kerosene and shake the contents vigorously for one minute; then set the tubes in the rack. Examine them at the close of the laboratory period (?).

e. Place exactly 3 g. of common salt in one test tube and an equal weight of potassium nitrate in another. Add to each exactly 1 cc. of water and heat the tube. If the solid does not dissolve, add an additional cubic centimeter of water and again heat. Repeat until the solid in each tube is dissolved. Compare the solubilities of the two solids in the boiling water.

Cool the solutions in each tube and note the approximate amounts of solids separating (?) (compare the results with the table of solubility of solids given in the Appendix).

**f.* Repeat Exercise 14, Experiments *a* and *b*, substituting a concentrated aqueous solution of common salt for the water (?).

EXERCISE 20

DETERMINATION OF THE SOLUBILITY OF COMMON SALT (QUANTITATIVE)

Apparatus. 60-cc. bottle; evaporating-dish with watch-glass cover; funnel; tripod and burner; thermometer.

Materials. 15 g. common salt; filter paper.

Place 15 g. of common salt in a 60-cc. bottle and add 40 cc. of water. Shake the mixture vigorously and set aside, repeating the shaking several times at intervals of from one or two minutes, so as to form a saturated solution. Note the temperature of the solution.

Accurately weigh the evaporating-dish and the watch-glass cover, then filter into the dish about 20 cc. of the saturated solution of salt, and weigh again. Set the watch glass aside and evaporate the solution (Fig. 31). After the solution has evaporated to dryness, cover the dish with the watch glass and heat it directly with the burner, regulating the flame so

that the tip barely touches the dish. Continue the heating until all the moisture has been expelled and the under part of the watch glass is free from moisture. (Do you see any reason for using the watch glass ?)

Now withdraw the burner, and after the dish is cool (room temperature) weigh once more. From your results calculate the approximate number of grams of salt that will dissolve in 1 liter of water at the temperature of the original solution.

If time permits, the solubility of other substances such as calcium sulfate and potassium dichromate may be determined in like manner; or different students may select different substances and compare their results.

EXERCISE 21

A METHOD FOR DETERMINING WHETHER OR NOT A GIVEN LIQUID IS A CONDUCTOR OF ELECTRICITY (OPTIONAL)

Apparatus. As shown in Fig. 53 (p. 103 of text); current from electric-lighting system.

Materials. 1 g. common salt dissolved in 25 cc. water; 1 g. sugar in 25 cc. water; 5 cc. sodium hydroxide solution added to 20 cc. water; 5 cc. sulfuric acid added to 20 cc. water; tap or well water; 5 cc. hydrochloric acid added to 20 cc. water.

If an electric-lighting current is available, test the conductivity of the following substances as explained on page 103 of the text, using the apparatus shown in Fig. 53 of the text: (1) distilled water, (2) distilled water containing a few drops of sulfuric acid, (3) hard water from a well, (4) a solution of common salt, (5) a solution of sugar, (6) hydrochloric acid, (7) a solution of sodium hydroxide. *The apparatus must be carefully cleaned with distilled water after testing each solution* (?). Tabulate the results.

EXERCISE 22

THE PROPERTIES OF ACIDS, BASES, AND SALTS

Apparatus. 3 small beakers; stirring-rod; evaporating-dish; ring stand and burner.

Materials. A few drops of each of the following acids: hydrochloric, sulfuric, nitric, acetic (R. S.); solutions of the following bases: sodium hydroxide, potassium hydroxide (R. S.), calcium hydroxide (R. S.); strips of blue and of red litmus paper.

a. Prepare a dilute solution of each of the following acids by adding 1 or 2 drops of the acid to 10 cc. of water: hydrochloric, nitric, sulfuric, acetic.

By means of a clean glass rod transfer a drop of each to a piece of blue litmus paper. Note the result. In a similar way try their effect on red litmus paper. Taste *one* drop of the dilute solutions (rinse the mouth with water after tasting).

Compare the formulas of the acids. In what respect are the acids similar in composition?

b. In a similar way try the effect on red litmus paper of a solution of each of the following bases: sodium hydroxide, potassium hydroxide, calcium hydroxide. Do they affect the blue litmus paper? Taste a drop of the calcium hydroxide solution.

Compare the formulas of the bases. In what respect are the bases similar in composition?

c. Dilute 5 cc. of the ordinary laboratory solution of sodium hydroxide (1 part of the hydroxide to 10 parts of water) with an equal volume of water. To this solution add 4 or 5 drops of hydrochloric acid (R). Stir the resulting solution with a glass rod and test its action on blue and on red litmus paper. Has it acid or basic properties?

Now continue to add the acid drop by drop until the resulting solution is neutral (that is, has no effect on either blue or

red litmus paper) or is at most slightly acid. Pour the solution into an evaporating-dish and evaporate to dryness. What compound remains? Taste it.

What is the name given to the compounds formed by the interaction of acids and bases?

d. Characterize acids and bases (1) as to composition, (2) as to their action on litmus, (3) as to taste, (4) as to their conductivity (recall Exercise 21), (5) as to their interaction with each other.

EXERCISE 23

THE RATIO OF ACID TO BASE IN NEUTRALIZATION (QUANTITATIVE)

Apparatus. 2 burettes and supports, as shown in Fig. 28; small beaker and stirring-rod.

Materials. Sodium hydroxide solution prepared by adding 20 cc. of the laboratory reagent to 100 cc. water; 1 cc. sulfuric acid added to 100 cc. water; a few drops of a phenolphthalein solution (R. S.).

(Two students may work together.)

Rinse out a burette, first with distilled water and then with a little of the solution of sodium hydroxide. Support the burette (Fig. 28), and pour into it the hydroxide solution until the level of the liquid is 1 or 2 cm. above the zero mark. Turn the stopcock and let the solution flow out until the bottom of the curved surface (meniscus) of the liquid in the burette is on a level with the zero mark. In a similar way fill a second burette with the acid solution.

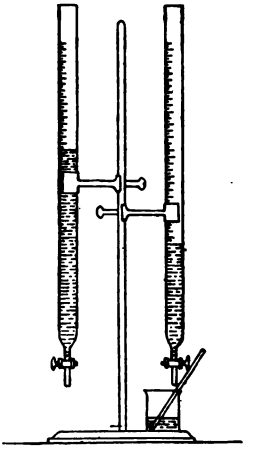


FIG. 28

Now let exactly 15 cc. of the acid solution flow into a small beaker, add two drops of phenolphthalein solution, and run in 2 or 3 cc. of the hydroxide solution. Notice that where the liquids come in

contact a reddish color is produced, which disappears quickly on stirring. Run in more of the solution, a little at a time, until the color fades slowly, and then a drop at a time until the entire liquid, on stirring, remains colored *faintly* pink. This marks approximately the point of neutralization. Note the number of cubic centimeters of the hydroxide solution used.

Repeat the experiment, using different volumes of acid, say 10 cc. and 20 cc. Calculate in each case the number of cubic centimeters of the hydroxide solution required to neutralize 1 cc. of the acid solution. What do the results prove?

EXERCISE 24

THE DISPLACEMENT OF METALS FROM THEIR COMPOUNDS

Apparatus. 4 test tubes; test-tube rack.

Materials. 4 strips each of zinc and copper (1 cm. × 10 cm.); 0.5 g. lead nitrate dissolved in 10 cc. water; 0.5 g. copper nitrate dissolved in 10 cc. water; 0.5 g. mercuric nitrate dissolved in 10 cc. water; 3 cc. sulfuric acid dissolved in 10 cc. water.

a. Pour into separate test tubes to a depth of 4 or 5 cm. solutions of the following compounds: (1) lead nitrate, (2) dilute sulfuric acid, (3) copper nitrate, (4) mercuric nitrate. Set the tubes in a rack in the order given above and label them "A," "B," "C," and "D" respectively.

Now place in each tube a strip of zinc. (It is convenient to have a strong thread attached to the upper part of each strip so that the strip may easily be withdrawn from the tube.) Note any change taking place in the appearance of the zinc.

After from twenty to thirty minutes withdraw the strips and wipe them carefully on a piece of white paper. Note any evidence tending to show that the zinc has displaced the lead, hydrogen (p. 113 of text), copper, and mercury from their salts. Has the solution of copper nitrate faded in color? (Metals in a very finely divided form are as a rule black.)

b. Repeat Experiment *a*, substituting for the zinc a strip of copper. Contrast the results obtained with those obtained in *a*. How do you account for the change in the color of the solution of mercuric nitrate after the addition of the copper strip? Are your results in accord with the displacement-series table given on page 112 of text?

EXERCISE 25

VALENCE

It is suggested that the laboratory period be spent in solving the exercises on page 120 of the text. The answers should be written on the board and criticized by the class.

EXERCISE 26

THE PREPARATION AND PROPERTIES OF AMMONIA

Apparatus. Test tube; hard-glass test tube fitted with cork and tubing as shown in Fig. 29; ring stand and burner; three 250-cc. wide-mouthed bottles; piece of window glass.

Materials. Solution of sodium hydroxide; 9 g. ammonium chloride; 15 g. powdered slaked lime (slaked or hydrated lime, $Ca(OH)_2$); red litmus paper; 5 cc. red litmus solution prepared by heating a bit of litmus in water and filtering.

a. Dissolve 0.5 g. of ammonium chloride in 3 or 4 cc. of water in a test tube and heat to boiling. Note the odor (?).

Now add 5 cc. of a solution of sodium hydroxide to the hot solution of ammonium chloride and continue the heating. Again note the odor (?). Moisten a strip of red litmus paper and hold it at the mouth of the tube but not in contact with it (?).

Dip the end of a glass rod in a concentrated solution of hydrochloric acid and hold it in the mouth of the test tube (?).

Complete the following equations:

$$NH_4Cl + NaOH \longrightarrow$$
$$NH_3 + H_2O \longrightarrow$$
$$NH_4OH\ (NH_3 + H_2O) + HCl \longrightarrow$$

b. *Usual laboratory method for preparing ammonia.* This differs from the method used in ***a*** only in the fact that the less expensive calcium hydroxide (slaked lime) is substituted for the sodium hydroxide. The form of apparatus used is shown in Fig. 29. The bottle *B* (250-cc.) contains 25 cc. of water. The glass tube *C* extends through a hole in a cardboard resting on the mouth of the bottle. The end of the tube must *just touch* the water in the bottle.

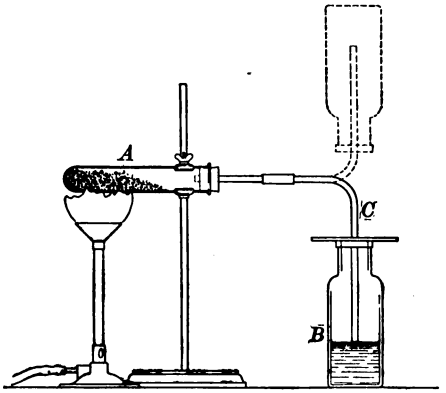


FIG. 29

Place in the tube *A* a mixture of 15 g. of powdered slaked lime and 8 g. of ammonium chloride. Connect the tube as shown in Fig. 29 and heat the mixture gently, beginning with that portion near the mouth of the tube and gradually extending the heat to the other portions. As soon as the gas is evolved freely (as shown by the bubbles at the end of the tube *C*), bring the tube *C* to an upright position, as shown in the dotted lines, and collect two bottles of the gas. To do this, bring the bottles successively down over the exit tube, leave each in this position until a drop of hydrochloric acid on the end of a glass rod fumes strongly when held at the mouth of the bottle (?), then withdraw the bottle, cover its mouth with a glass plate, and set it aside, mouth downward.

When both bottles are filled, bring the tube *C* into the bottle *B* again and continue to heat the mixture gently as long as any gas is generated. Write the equations for all the reactions involved.

c. Note the color and odor of the gas. Is it heavier or lighter than air?

d. Test a bottle of the gas with a burning splint. Describe the results.

e. Fill a large beaker with water and color it with a few drops of red litmus solution. Uncover the remaining bottle of the gas and at once bring its mouth under the surface of the water in the beaker. Hold in this position for five minutes, taking care to keep the mouth of the bottle below the surface of the water. What do the results prove?

f. Note the odor of the liquid in the bottle *B*. Try its effect on blue and on red litmus paper. How does it compare with the aqua ammonia of the druggist in its odor and its action on litmus? Does the gas combine with the water, or is it simply dissolved in the water? Give reasons for your answer. Now neutralize the liquid with hydrochloric acid (R) and evaporate just to dryness. Compare the residue with the ammonium chloride used in Experiment *a*.

EXERCISE 27

THE PREPARATION AND PROPERTIES OF NITRIC ACID

Apparatus. Glass retort (150-cc.), test tube, and beaker (500-cc.), arranged as shown in Fig. 30; funnel; evaporating-dish; ring stand and burner.

Materials. 12 g. sodium nitrate; 10 cc. sulfuric acid; small piece of tin; small strip of copper.

a. Arrange an apparatus like that shown in Fig. 30. Put in the retort *A* about 12 g. of sodium nitrate and 10 cc. of sulfuric acid, pouring the latter through a funnel placed in the

tubulus *B* of the retort. Heat the mixture gently with a small flame. Nitric acid is set free (R), distills over, and is condensed in the test tube *C*, which is kept cold by being partly immersed in ice water in the beaker *D*.

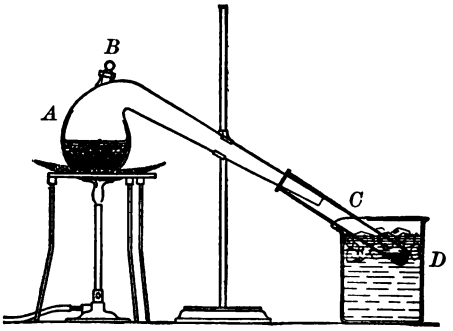


FIG. 30

b. When nitric acid is heated a part of it is decomposed into water, nitrogen dioxide, and oxygen (R). On this account it is a good oxidizing agent. To test its oxidizing properties, put a small piece of tin in a test tube, cover it with a little nitric acid, and gently heat (hood). The white residue formed is composed mainly of tin and oxygen, the latter being supplied by the nitric acid.

Pure nitric acid is colorless. How do you account for the color of the acid which you have prepared?

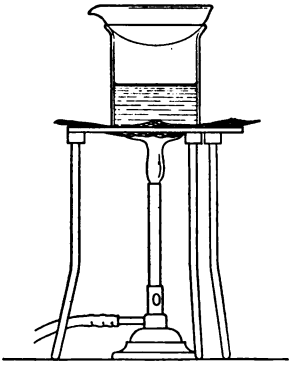


FIG. 31

c. Place a small strip of copper in an evaporating-dish (hood) and add some of the acid you have prepared, a few drops at a time, until the copper is just dissolved. Evaporate the solution to dryness (Fig. 31). (The beaker is half filled with water which is kept boiling; the steam heats the dish, causing the solution to evaporate.) Note the appearance of the residue. Since copper is below hydrogen in the displacement series, how do you account for the fact that nitric acid dissolves the metal (study the reaction on page 130 of text)? Save the residue in the dish (what is it?) for use in the following experiment.

EXERCISE 28

THE PROPERTIES OF THE SALTS OF NITRIC ACID (NITRATES)

Apparatus. Evaporating-dish containing the copper nitrate prepared in Exercise 27; 5 test tubes in test-tube rack.

Materials. Strip of copper; crystal of lead nitrate; crystals of such nitrates as are available; sulfuric acid; 2 g. ferrous sulfate dissolved in 10 cc. water.

a. Heat the dish (hood) containing the copper nitrate, prepared in Exercise 27, with a small flame. Note the color of the gas evolved, also the color of the residue (?) Compare the residue with the crust of copper oxide prepared by holding a strip of copper in a flame.

b. Place a crystal of lead nitrate in the evaporating-dish and heat gently. Compare with the results obtained in ***a.***

c. Place a small crystal of such nitrates as are available in your laboratory in separate test tubes and test their solubility in water. What nitrates are insoluble in water (p. 131 of text)?

d. *How to detect the presence of nitrates.* Dissolve a crystal of sodium nitrate in 2 or 3 cc. of water in a test tube, add an equal volume of sulfuric acid, mix, and cool. The sulfuric acid acts on the nitrate, liberating nitric acid. Now tip the tube slightly and gently pour 2 or 3 cc. of the solution of ferrous sulfate down the side of the tube, so that it floats on the heavier liquid, and set the tube aside, being careful not to mix the two liquids. A brown ring soon forms where the liquids meet. Repeat the experiment, using potassium nitrate. This is a good test for nitrates. The brown ring is due to the presence of a complex compound formed by the action of ferrous sulfate on nitric acid.

EXERCISE 29

THE PREPARATION AND PROPERTIES OF SOME OF THE OXIDES OF NITROGEN

Apparatus. Hard-glass test tube, with delivery tube, as used in preparing oxygen (Fig. 13); 3 wide-mouthed bottles (250-cc.); pneumatic trough; hydrogen generator (Fig. 18).

Materials. 8 g. ammonium nitrate; wooden splints; 5 small strips of copper; 10 cc. nitric acid.

a. Nitrous oxide. Put 6 or 8 g. of ammonium nitrate in the hard-glass test tube used in the preparation of oxygen. Attach a delivery tube and heat *gently*, applying no more heat than is necessary to cause a gentle evolution of the gas.

As soon as the gas is regularly evolved, collect two or three bottles of it over water. Notice the water deposited on the sides of the test tube. What is the source of it? Note the color, odor, and taste of the gas. Test it with a glowing splint. Account for the result. How can you distinguish nitrous oxide from oxygen?

b. Nitric oxide and nitrogen dioxide. Put a few pieces of copper in your hydrogen generator (hood), just cover them with water, and add 2 or 3 cc. of nitric acid. Collect over water two bottles of the evolved gas, adding more nitric acid to the liquid in the generator if necessary.

Compare the color of the gas in the generator with that collected in the bottles and account for any difference. Write the equations for all the reactions involved.

Uncover one of the bottles of the gas and account for the result (R). Test the gas in the second bottle with a burning splint. Which is the more stable, nitrous oxide or nitric oxide? Give reasons for your answer.

EXERCISE 30

REVERSIBLE REACTIONS; HYDROLYSIS

Apparatus. 6 test tubes; test-tube rack.

Materials. Silver nitrate solution (R. S.); a crystal of sodium chloride dissolved in 5 cc. water; 0.3 g. of each of the following salts dissolved in separate portions (3 cc.) of water: potassium nitrate, common salt, borax, sodium carbonate, alum.

a. What is meant by a *reversible reaction* (p. 135 of text)? The reaction used in the preparation of nitric acid (Exercise 27) is reversible; how can it be made to complete itself?

b. Add 2 or 3 drops of a solution of silver nitrate to 5 cc. of a dilute solution of sodium chloride (common salt). Note the result and explain.

c. Recall the process of neutralization. To what extent are such reactions completed reactions?

d. Pour into separate test tubes small amounts of solutions of (1) potassium nitrate, (2) sodium chloride, (3) borax (p. 270 of text), (4) sodium carbonate (p. 282 of text), (5) alum (p. 328 of text). Test the action of each on blue and on red litmus paper, note the results, and explain.

EXERCISE 31

THE PROPERTIES OF SULFUR

Apparatus. 3 test tubes; smallest-sized beaker; magnifying-glass; porcelain crucible; ring stand and burner; large beaker.

Materials. 5 cc. carbon disulfide; 20 g. powdered sulfur; strip of copper; 5 g. iron powder.

a. Examine the physical properties of a piece of brimstone. Pour 2 or 3 cc. of carbon disulfide (hood) (*keep carbon disulfide away from flame and do not inhale the vapor*) over 3 g. of

powdered brimstone in a test tube. Cover the mouth of the tube with the thumb and shake the contents gently until the sulfur is dissolved, adding more carbon disulfide if necessary. Pour the clear solution into a small beaker, cover it loosely with a filter paper, and set it aside in the hood. The carbon disulfide soon evaporates, the sulfur being deposited in crystals. Examine these with a magnifying-glass (?).

b. Half fill a test tube with powdered brimstone and heat it gently until the sulfur is just melted. Note the properties of the liquid.

Now apply a stronger heat and observe that the liquid becomes darker and at a certain temperature (200°–250°) is so thick that the tube may be inverted without spilling it.

Finally, increase the heat until the sulfur boils (448°), and then pour the boiling liquid into a beaker of cold water. Examine the product. What name is given to this form of sulfur? Expose it to the air for an hour. Have its properties remained unchanged?

c. Fill a porcelain crucible with powdered brimstone and apply a very gentle heat until the sulfur is just melted. Withdraw the flame and examine the liquid carefully as it cools. Crystals soon begin to form on the surface of the melted sulfur, rapidly extending from the circumference toward the center. Before they reach the center, quickly pour off the remaining liquid and examine the crystals. Contrast them with those formed in *a.* In how many forms have you obtained sulfur?

d. Burn a small piece of sulfur. Note the appearance of the burning sulfur and the odor of the gas formed (?).

e. Boil a little sulfur in the test tube used in *b*, and drop a small strip of hot copper foil into the boiling liquid. Is there any visible evidence of a chemical change? What is formed?

Grind together some iron powder with an equal weight of sulfur and heat the mixture in a test tube (?).

EXERCISE 32

THE PREPARATION AND PROPERTIES OF HYDROGEN SULFIDE

Apparatus. Hydrogen generator and tubes, as shown in Fig. 32; 2 wide-mouthed bottles (250-cc. and 60-cc.); funnel; evaporating-dish.

Materials. 10 g. ferrous sulfide; 20 cc. hydrochloric acid added to 20 cc. water; 3 cc. nitric acid; blue and red litmus paper; silver coin; filter paper.

a. (Hood.) Attach a delivery tube to the hydrogen generator, as shown in Fig. 32. Put into the generator *A* a few pieces of ferrous sulfide (FeS) and insert the stopper. Now pour a little water through the funnel tube of the generator until the end of the tube just dips below the surface of the water; then pour in a few drops of hydrochloric acid, adding more from time to time, if necessary, to maintain a gentle evolution of the gas (R). The gas escapes into the bottle *B*, which gradually becomes filled. Note the odor and color of the evolved gas (*the gas is poisonous if inhaled in concentrated form*). Continue the evolution of the gas until it is ignited by a flame held at the mouth of the bottle *B*. Account for the deposit on the sides of the bottle (?).

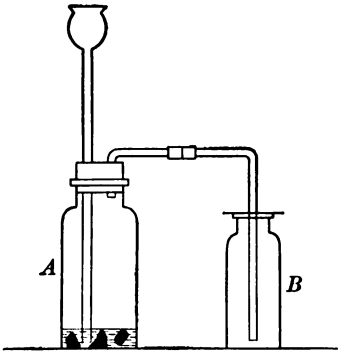


FIG. 32

b. Replace the bottle *B* with a 60-cc. bottle half filled with water, and allow the gas from the generator (add more acid if necessary) to bubble through the water for one or two minutes. Test the resulting solution with blue and with red

litmus paper. What is the solution called? How does it compare with the so-called "sulfur water" of many springs?

Drop a silver coin into the solution and account for the results. Why do certain foods, as eggs, blacken silver spoons?

c. Pass a few bubbles of hydrogen sulfide through 3 cc. of nitric acid. Sulfur separates as a white solid (?). Account for the fact that sulfur waters deposit sulfur on exposure to air.

**d.* Filter off the liquid left in the generator and evaporate (hood) to dryness in an evaporating-dish. Note the results.

EXERCISE 33

THE PREPARATION AND PROPERTIES OF THE SALTS OF HYDROSULFURIC ACID (SULFIDES)

Apparatus. Hydrogen generator and connections, as shown in Fig. 33; 6 test tubes; funnel; watch glass.

Materials. Ferrous sulfide and dilute hydrochloric acid, as used in Exercise 32; separate solutions of silver nitrate, copper sulfate, cadmium chloride, lead nitrate, and sodium chloride, made by dissolving about 0.5 g. of the solid in 5 cc. water (solutions on reagent shelf may be used); 5 filter papers; sulfuric acid; lead acetate (R.S.).

a. Charge the hydrogen sulfide generator as in Exercise 32 and pass a few bubbles of the gas (Fig. 33) through each of the following solutions: (1) silver nitrate, (2) copper sulfate, (3) cadmium chloride, (4) sodium chloride, (5) lead nitrate. The exit tube *C* through which the gas bubbles into the solutions must be thoroughly cleaned each time (?). Note the color of the precipitates obtained. Write the equations for the reactions

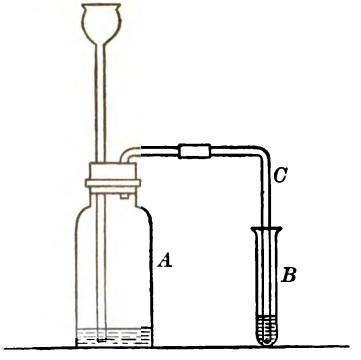


FIG. 33

involved. Do any of the solutions fail to give a precipitate? How do you account for this?

b. Intimately mix 5 g. of sulfur with 3 g. of powdered lime. Transfer to a beaker and add 150 cc. of water. Stir the mixture and heat just to boiling for ten minutes. Now fill a test tube with the resulting mixture, cork the tube loosely, and set it aside until the end of the laboratory period; then examine. Describe the results. For what is the solution used? What is its composition (p. 144 of text)?

c. Test for hydrogen sulfide. Dip a strip of filter paper into a solution of lead acetate. Remove the cork from the hydrogen sulfide generator and insert the paper for a moment. Note the results (R). This serves as a convenient test for the gas. What property would also serve to detect it if present in any marked quantity?

d. Test for sulfides. Filter off the precipitated sulfides obtained in *a*, and wash them with water until the odor of hydrogen sulfide is no longer noticeable. Transfer each in succession to a watch glass and add to the solid 1 or 2 drops of sulfuric acid. Carefully note the odor. Most of the sulfides when treated in this way evolve hydrogen sulfide, which can be detected by the odor.

All sulfides when heated in air evolve sulfur dioxide (formed by the combustion of the sulfur present), which has the characteristic odor of burning sulfur. Heat a little iron sulfide in the flame of the burner and note the odor.

EXERCISE 34

SULFUR DIOXIDE AND SULFUROUS ACID

Apparatus. 250-cc. flask fitted with funnel tube and glass exit tube, as shown in Fig. 34; ring stand and burner; 3 bottles (250-cc.); 2 test tubes; evaporating-dish.

Materials. 10 g. copper; 25 cc. sulfuric acid; blue litmus paper; sodium hydroxide solution; strips of colored calico or a red flower.

(Hood.) Place about 10 g. of copper turnings or small pieces of sheet copper in a generator arranged as in Fig. 34. Add 25 cc. of concentrated sulfuric acid and apply a gentle heat. As soon as the action begins (R), lower the flame, regulating it so as to obtain a uniform evolution of the gas. Collect two bottles of the gas by displacement of air; then cause it to bubble through 50 cc. of water as long as any is dissolved.

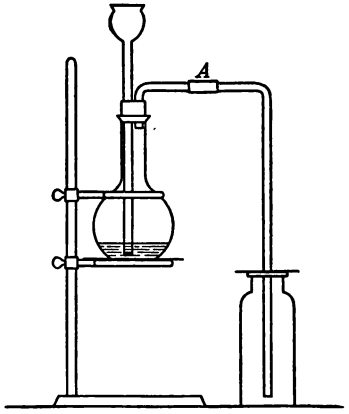


FIG. 34

Note the odor of the gas. Is the gas combustible?

Invert one of the bottles of the gas so that its mouth is under water, and examine after several minutes (?). Account for the results.

Test the saturated aqueous solution of the gas with blue litmus paper. Is the gas combined with the water or simply dissolved in it?

Set aside 10 cc. of the solution for a future experiment (Exercise 35) and divide the remainder into two equal parts. Immerse in the one part some small strips of colored calico or some petals of a red flower and note any results.

To the remainder of the liquid add a solution of sodium hydroxide, drop by drop, until neutral (R), and evaporate just to dryness. What is the residue? Moisten it with 2 or 3 drops of sulfuric acid and note the odor of the evolved gas (?). *All sulfites evolve sulfur dioxide when treated with sulfuric acid.* This reaction serves as a good test for sulfites.

EXERCISE 35

A STUDY OF SULFURIC ACID

Apparatus. Burner; 5 test tubes.

Materials. Sulfuric acid; 2 pieces of granulated zinc; splint; 0.5 g. sugar; barium chloride solution (R.S.); hydrochloric acid; nitric acid; sulfurous acid prepared in Exercise 34; bit of charcoal (size of a bean).

a. Heat a bit of charcoal with 1 or 2 cc. of sulfuric acid. What gas is evolved (odor)? Account for the formation of this gas, recalling that carbon has a strong affinity for oxygen.

b. Into one test tube pour 3 cc. of water and add 5 drops of sulfuric acid; into another test tube pour 3 cc. of concentrated sulfuric acid. Drop a small piece of zinc into each tube. If no reaction takes place, heat the acid gently. Test with a lighted splint the gas evolved by the action of the dilute acid on zinc. Note the odor of the gas evolved by the action of the concentrated acid on the metal. Account for the difference in the action of the dilute and the concentrated acid.

c. Put a drop of concentrated sulfuric acid on a splint. Pour a few drops on 0.5 g. of sugar in a test tube. Examine after a few minutes. Account for the results.

d. Recall the action of sulfuric acid on sodium nitrate (Exercise 27). What property of sulfuric acid enables it to be used in the preparation of nitric acid?

e. Add 3 drops of sulfuric acid to 5 cc. of water in a test tube. To this add a few drops of a solution of barium chloride.

Note that a precipitate forms (R). Now add 3 or 4 drops of hydrochloric acid. Does the precipitate dissolve? *The formation with barium chloride of a precipitate which is insoluble in hydrochloric acid* constitutes a good test for sulfuric acid.

f. Place 5 cc. of the solution of sulfur dioxide obtained in Exercise 34 in a test tube, add 1 cc. of concentrated nitric acid, and heat gently. Cool and test with barium chloride solution (?).

EXERCISE 36

SALTS OF SULFURIC ACID (SULFATES)

Apparatus. 6 test tubes.

Materials. Crystals or small amounts (0.1 g.) of the sulfates available in the laboratory; 2 cc. barium chloride solution (R.S.); hydrochloric acid.

a. Examine the physical properties of (1) sodium sulfate, (2) calcium sulfate, (3) barium sulfate, (4) copper sulfate, (5) magnesium sulfate, (6) ferrous sulfate, (7) such other sulfates as are available.

Test the solubility of each of the above sulfates in water. What sulfates are insoluble (p. 275 of text)?

b. Prepare a dilute solution of different sulfates by dissolving a crystal of each in 2 or 3 cc. of water. Add to each 1 drop of barium chloride solution (?). Add 1 or 2 drops of hydrochloric acid to the mixture in each tube. Does the precipitate dissolve? *All soluble sulfates give in solution a white precipitate ($BaSO_4$) with barium chloride solution, which precipitate is insoluble in hydrochloric acid.* This reaction serves as a good test for sulfates.

It will be noted that both sulfuric acid and its salts give with barium chloride the same product, namely, a white precipitate of barium sulfate. This is evident from the following facts. It will be recalled (Chap. XIII) that both acids

and salts are ionized in solution. In the case of sulfuric acid and sulfates, ions are formed as follows:

$$H_2SO_4 \longrightarrow H^+,\ H^+ + SO_4^{--}$$
$$Na_2SO_4 \longrightarrow Na^+,\ Na^+ + SO_4^{--}$$
$$CuSO_4 \longrightarrow Cu^{++} + SO_4^{--}$$

Likewise, barium chloride solution contains the ions Ba^{++} and Cl^-, Cl^-. Now when a solution of barium chloride is mixed with any solution containing the SO_4^{--} ion, the two ions Ba^{++} and SO_4^{--} unite to form the insoluble $BaSO_4$, which precipitates; hence the reaction proceeds to completion (paragraph 2, p. 138 of text). *The barium chloride test is therefore really a test for the presence of the* SO_4^{--} *ion.* Since only sulfuric acid and its salts give this ion, however, it is customary to say that it is a test for sulfuric acid and the sulfates.

EXERCISE 37

THE PREPARATION AND PROPERTIES OF HYDROGEN FLUORIDE

Apparatus. Piece of window glass; small lead dish (laboratory outfit).

Materials. 2 or 3 small pieces of paraffin (size of a pea); 3 g. fluorite; sulfuric acid.

PRECAUTION. *Hydrogen fluoride is very corrosive and must not be inhaled; neither must its solution be brought in contact with the skin.*

Place some pieces of paraffin on a glass plate and gently warm over a small flame. When the paraffin is melted, tilt the plate about so as to form a uniform layer of the wax. When the wax is cold, scratch your name *through* the wax with a pin or other sharp point. Place 3 g. of fluorite in a lead dish and add sufficient sulfuric acid to make a paste of it. Cover the dish tightly with the waxed side of the glass plate and set it in the hood for an hour; then scrape off the paraffin and examine the glass. Write the equations for all the reactions involved.

EXERCISE 38

THE PREPARATION AND PROPERTIES OF CHLORINE

Apparatus. Test tube; apparatus as shown in Fig. 35 (*A* is a 250-cc. flask and *B* and *C* 250-cc. bottles; *B* contains some sulfuric acid); 4 additional 250-cc. bottles (dry); glass plates.

Materials. 25 g. manganese dioxide; hydrochloric acid; 1 g. sodium chloride; sulfuric acid; bit of powdered antimony; strip of copper foil; strips of colored calico; piece of printed paper (printer's ink); paper written over with ordinary ink.

PRECAUTION. *All of the following experiments must be performed in the hood, and great care must be taken not to inhale the chlorine.*

a. Place about 1 g. of manganese dioxide in a test tube, add 2 or 3 cc. of hydrochloric acid, and heat gently (R).

b. Repeat the experiment, replacing the hydrochloric acid with small amounts of common salt and sulfuric acid (R). The manganese dioxide and salt should first be mixed together and the sulfuric acid then added.

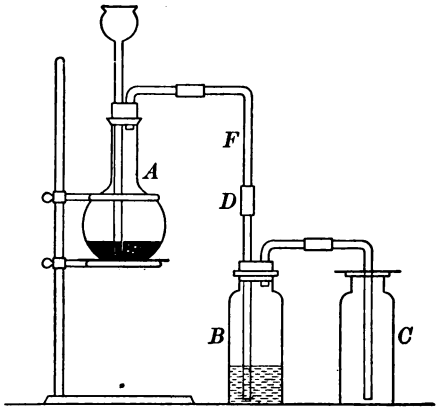


FIG. 35

c. *Usual laboratory method.* (Two students may work together.) Arrange an apparatus according to Fig. 35. Put into the flask from 20 to 25 g. of manganese dioxide. Insert the cork and pour 150 cc. of hydrochloric acid through the funnel tube. Shake the flask so as to mix the contents thoroughly. Warm gently, applying just enough heat

to cause a gentle evolution of the gas, but not sufficient to boil the liquid. The chlorine generated bubbles through the sulfuric acid in *B* (which removes all moisture) and is collected in *C*. Fill four bottles with the gas (note the color), cover them with glass plates, and set them aside.

Finally, prepare some chlorine water by bringing the exit tube into a bottle containing 50 cc. of water so that the gas bubbles up through the liquid. Continue the gentle heating until no more chlorine is absorbed; then cork the bottle, label it, and set it aside in a dark (?) place for future use.

d. Grind a fragment of antimony to a fine powder and sprinkle a pinch of the powder into one of the bottles of the gas. $SbCl_3$ is formed (R).

****e.*** Support by forceps a small piece of copper foil, heat it to redness, and *immediately* thrust it into a bottle of the gas. Describe the result. What is formed?

f. Suspend strips of colored calico in a bottle of the dry gas; also two strips of paper, the one with writing in ink on it, the other with printing (printer's ink) on it.

g. Repeat ***f***, using similar strips, but moistened with water. Describe the results in ***f*** and ***g***. What part does the water play in the bleaching?

EXERCISE 39

THE PREPARATION AND PROPERTIES OF HYDROGEN CHLORIDE AND OF HYDROCHLORIC ACID

Apparatus. Flask and bottle connected as shown in Fig. 36 (this is same as shown in Fig. 35, except that the glass tube extending into the bottle *B* does not touch the liquid (water) in *B*); two 250-cc. bottles (dry); burner; large beaker.

Materials. Dilute sulfuric acid prepared by slowly pouring (3 or 4 drops at a time with constant stirring) 30 cc. of the concentrated acid into 10 cc. water; 50 g. sodium chloride; 1 cc. blue litmus solution; blue litmus paper; splint.

a. Usual laboratory method of preparation. Put about 50 g. of common salt into the generator flask (Fig. 36), insert the cork, pour the cold dilute sulfuric acid through the funnel tube, mix the contents by a gentle motion of the flask, and after two or three minutes warm gently with a *small* flame. Notice the currents in the water in *B*. What causes them? As soon as the gas is evolved regularly, disconnect the generator flask at *D* long enough to collect two bottles of the gas by displacement of air (as in Fig. 34). Cover these tightly with glass plates and set them aside; then connect the generator with *B* again and continue to apply a gentle heat as long as any gas is evolved (R).

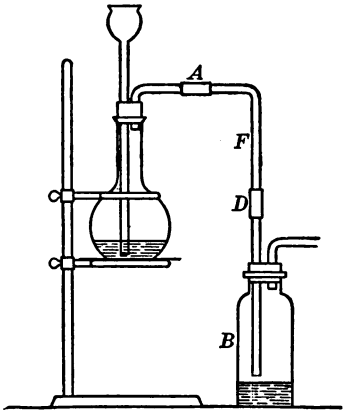


FIG. 36

b. What is the color of the gas (examine that in the generator)?

c. Test the gas in one of the bottles with a lighted splint. Is it combustible? Is it a supporter of combustion?

d. Fill a large beaker with water and color it with a few drops of a solution of blue litmus. Now uncover the remaining bottle, invert it, and at once bring its mouth under the surface of the water in the beaker. Describe the results. What does the experiment prove? Why not extend the tube in *B* (Fig. 36) to the bottom of the bottle?

e. Put a drop of the aqueous solution of the acid from bottle *B* on a bit of blue litmus paper. Note the result. Pour 2 drops of the solution into 3 or 4 cc. of water and taste a drop. Perform a test-tube experiment to prove the presence of chlorine in the acid (R); also one to prove the presence of hydrogen (R). How does the solution compare with the hydrochloric acid on your desk?

EXERCISE 40

THE TEST FOR HYDROCHLORIC ACID AND ITS SALTS (CHLORIDES)

Apparatus. 6 test tubes.

Materials. 2 cc. silver nitrate solution (R.S.); hydrochloric acid; nitric acid; ammonium hydroxide; crystals of different chlorides, such as those of sodium, calcium, and iron.

a. Add 4 or 5 drops of hydrochloric acid to 4 cc. of water, mix well, and add 2 or 3 drops of silver nitrate solution (?).

Divide the resulting mixture into two equal parts: to the one add ammonium hydroxide until the liquid is alkaline (?); to the other add 2 or 3 drops of nitric acid (?).

b. Examine the physical properties of such chlorides as are available. Test their solubility in water. What ones are insoluble (p. 275 of text)? Dissolve a crystal of different chlorides (such as sodium chloride, calcium chloride, ferric chloride) each in 5 cc. of water and add silver nitrate solution as in *a* (?). *The formation of a white precipitate (AgCl) with*

silver nitrate, which precipitate is soluble in ammonium hydroxide and insoluble in nitric acid, serves as a good test for hydrochloric acid and its salts.

How do you account for the fact that both hydrochloric acid and its salts react towards silver nitrate in the same way?

EXERCISE 41

THE PREPARATION AND PROPERTIES OF BROMINE AND OF HYDROGEN BROMIDE

Apparatus. Retort; test tube and beaker, as shown in Fig. 30; burner; funnel; 2 test tubes.

Materials. 3 g. potassium bromide or sodium bromide; 4 g. manganese dioxide; 10 cc. sulfuric acid dissolved in 40 cc. water; strips of colored calico; 1 cc. silver nitrate solution (R.S.).

PRECAUTION. *The vapor of bromine must not be inhaled. Perform the experiments in a hood.*

a. Put into the retort a mixture of 2 g. of potassium bromide or of sodium bromide and 4 g. of manganese dioxide, and add to this through a funnel a cold dilute solution of sulfuric acid. Shake the retort so as to mix the contents thoroughly. The test-tube receiver should contain sufficient water to allow the end of the retort to dip just below its surface.

Now heat the retort gently. The bromine is liberated and distills over (R). Continue the heating until all the bromine has distilled over. Remove the stopper from the retort before the heat is withdrawn.

b. Note the properties of the bromine collected in the bottom of the receiver. Has any dissolved in the water? What property is implied in the name of the element?

Test the bleaching property of the aqueous solution. How does it compare with chlorine as a bleaching agent?

c. Add 3 or 4 drops of sulfuric acid to about 1 g. of potassium bromide in a test tube. Some hydrogen bromide is evolved, which attracts moisture as it escapes from the tube,

forming a light cloud (test the vapor with a moist piece of blue litmus paper). At the same time there appears in the tube a reddish vapor. Explain.

d. Hydrobromic acid is unstable and is but little used. Its salts (bromides) are stable. Study the properties of potassium bromide as well as of any other available bromides.

Dissolve a crystal of potassium bromide in 5 cc. of water and apply the silver nitrate test as outlined for testing for chlorides in Exercise 40 (?).

EXERCISE 42

THE PREPARATION AND PROPERTIES OF IODINE AND OF HYDROGEN IODIDE

Apparatus. Retort and connections, as shown in Fig. 30; burner.

Materials. 4 g. potassium iodide (or sodium iodide); 4 g. manganese dioxide; sulfuric acid; chlorine water reserved in Exercise 38; silver nitrate solution (R.S.); starch solution (R.S.).

a. Introduce into the retort a mixture of 2 g. of potassium iodide and 4 g. of manganese dioxide. Pour over this mixture 5 cc. of sulfuric acid. Insert the stopper and apply a gentle heat (R). Note the vapor of the iodine in the bulb of the retort; also note the grayish-black crystals, which are soon deposited in the neck of the retort. What property does the name of the element suggest?

b. Half fill two test tubes with starch solution. To the first add a few drops of a solution of iodine prepared by shaking a small crystal in water (?). To the second add a few drops of an aqueous solution of potassium iodide (?). Now add to the second tube 2 or 3 drops of chlorine water and mix the contents (?). Determine whether the chlorine water alone changes the color of the starch. What is the function of the chlorine water added to the second tube?

Dissolve a crystal of iodine in alcohol. What is the solution called?

c. Hydrogen iodide is still less stable than hydrogen bromide. What reaction would you expect to take place when concentrated sulfuric acid is added to a crystal of potassium iodide? (Compare *c*, Exercise 41.) Try the reaction and note any evidences in favor of your opinion.

d. The salts of hydriodic acid: the iodides. While hydriodic acid is unstable, its salts are stable. Study the properties of potassium iodide. Prepare a solution of the salt and study the action upon it of silver nitrate, as in the case of chlorides and bromides.

EXERCISE 43

HOW TO DISTINGUISH BETWEEN CHLORIDES, BROMIDES, AND IODIDES

Apparatus. 3 test tubes.

Materials. 0.2 g. each of the chloride, the bromide, and the iodide of either potassium or sodium, dissolved separately in 5 cc. water; 5 cc. carbon tetrachloride; 10 cc. chlorine water reserved in Exercise 38.

a. Recall the action of silver nitrate solution upon solutions of chlorides, bromides, and iodides (?).

b. Pour the solutions of the chloride, of the bromide, and of the iodide of potassium (or sodium) into separate test tubes and set the tubes in a rack in the order given.

Add to each solution 1 cc. of carbon tetrachloride (carbon disulfide will do as well but is poisonous). Shake the contents of the tubes and set them aside for two or three minutes (?). Add to each tube 2 or 3 cc. of chlorine water and shake again the contents of the tubes vigorously and set aside for a few minutes (?). Explain the action of the chlorine water.

The silver nitrate test will enable you to tell whether or not a given compound belongs to the group of chlorides, bromides, and iodides. The test with chlorine water and carbon tetrachloride will enable you to distinguish the three members of the group from one another.

EXERCISE 44

METHODS FOR DETECTING THE SALTS OF CERTAIN ACIDS

Recall the tests for nitrates (Exercise 28), sulfides (Exercise 33), sulfites (Exercise 34), sulfates (Exercise 36), chlorides, bromides, and iodides (Exercise 43). Obtain from your instructor unknown samples of compounds belonging to the above classes of salts and determine to which class each sample belongs.

EXERCISE 45

THE FORMATION OF CHARCOAL AND COKE

Apparatus. Hard-glass test tube *A* connected as shown in Fig. 37; *B* is a test tube fitted with a glass tube *C* drawn to a jet; large beaker; porcelain dish; burner.

Materials. Small pieces of hard wood (sawdust will do) sufficient to half fill the hard-glass test tube; pieces of soft coal sufficient to half fill the test tube; blue and red litmus paper.

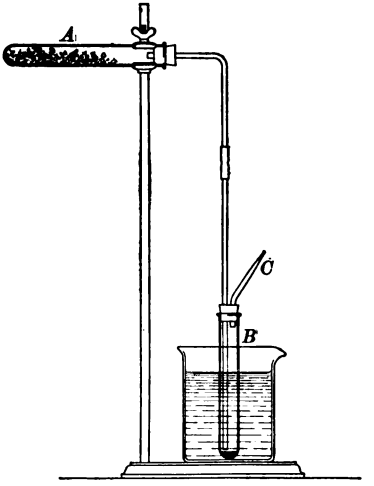


FIG. 37

a. Half fill the tube *A* (Fig. 37) with hard-wood splints or sawdust and connect it as shown in the figure. The tube *B* is kept cool by ice water in the beaker. Heat the wood in *A*, gradually increasing the heat until no further change takes place. During the heating, test the gas escaping from the jet *C* to determine whether it will burn (?).

When the tube *A* is cool, remove the residue (?). Note its properties. Is it combustible ?

Note the odor and appearance of the liquid condensed in *B*, also its action on blue and on red litmus paper (?). Name two important compounds prepared commercially from the liquid obtained by heating hard wood in the absence of air (paragraph 2, p. 196 of text).

The process of heating a substance like wood and coal, in the absence of air, is known as *destructive distillation.*

b. Repeat Experiment ***a***, substituting small pieces of *soft* coal for the wood. Describe the results. What is left in the tube *A*? The liquid condensed in *B* is known as *coal tar* (p. 210 of text). Note its appearance and odor.

EXERCISE 46

A FURTHER STUDY OF CARBON

Apparatus. Hard-glass test tube; porcelain dish; burners; funnel.
Materials. 3 g. sugar; test tube one-fourth full of bone black; 1 cc. litmus solution; filter paper; common acids; 3 g. copper oxide and an equal bulk of powdered charcoal; 5 cc. limewater (R.S.).

a. Heat 2 or 3 g. of sugar in a test tube until no further change takes place. Note the results. What is the residue left in the tube ?

b. Bring a cold porcelain dish into a small luminous Bunsen flame. Note the deposit. What is this form of carbon called ? In what other forms does carbon exist ? What properties have all of these forms in common ?

c. Put one-fourth test tube full of bone black into a small flask and pour over it about 50 cc. of water, to which has been added a few drops of a solution of litmus or indigo. Thoroughly mix the contents of the flask, then heat gently for a few minutes, and filter. If the filtrate is not decolorized, repeat the process, using more bone black. What is

the composition of bone black (p. 197 of text)? By what other name is it known? What use does this experiment suggest for it?

d. Is carbon an active element at ordinary temperatures? Test it with the common acids. How does the charring of wood preserve it?

e. In a hard-glass test tube heat an intimate mixture of 2 or 3 g. of black copper oxide and an equal bulk of powdered charcoal. The copper oxide is reduced to copper, the oxygen combining with the hot carbon to form carbon dioxide.

EXERCISE 47

A STUDY OF CARBON DIOXIDE

Apparatus. Hydrogen generator with connections, as shown in Fig. 32; three 250-cc. bottles; small beaker or test tube; hard-glass test tube.

Materials. 5 pieces of marble (size of walnuts); hydrochloric acid; splints; limewater (R.S.); 3 g. of copper oxide and an equal bulk of powdered charcoal.

a. Usual laboratory method for preparing carbon dioxide. Place some pieces of marble in your hydrogen generator and connect as shown in Fig. 32. Add water through the funnel tube until the marble is covered with the liquid; then add hydrochloric acid, a few drops at a time. Collect three bottles of the gas by displacement of air. To test when filled, hold a burning splint at the mouth of the bottle; the gas will extinguish the flame.

b. Thrust a burning splint into one of the bottles of the gas (?). The results suggest what use for the gas?

c. Devise an experiment to show whether the gas is heavier or lighter than air. Attempt to pour it from one bottle to another, as you would a liquid, and test with a burning splint for its presence in the second bottle (?).

d. Pass a few bubbles of the gas through 10 cc. of lime-water (?) (p. 201 of text). This serves as a good test for carbon dioxide.

e. Prove that the air exhaled from the lungs contains carbon dioxide (?); also prove that it is formed when ordinary fuels burn.

**f.* Repeat Exercise 46, Experiment *e*, and prove that carbon dioxide is evolved.

EXERCISE 48

CARBONIC ACID AND ITS SALTS (CARBONATES)

Apparatus. Hydrogen generator, as used for preparing carbon dioxide in Exercise 47; small beaker; 5 test tubes.

Materials. Pieces of marble for generating carbon dioxide; hydrochloric acid; blue litmus paper; 5 cc. sodium hydroxide solution diluted with 10 cc. water; 1 g. of the common carbonates, such as sodium carbonate, magnesium carbonate, calcium carbonate; 25 cc. limewater (R.S.).

a. Generate carbon dioxide and pass the gas through 25 cc. of water. The gas combines with the water to form carbonic acid (R). Taste the liquid. Is the acid formed strong enough to affect blue litmus paper?

b. Pass carbon dioxide through a solution of sodium hydroxide until the gas is no longer absorbed; then evaporate the solution to dryness. Explain. Could a solution of sodium hydroxide be used in place of a solution of calcium hydroxide (limewater) in testing for carbon dioxide?

c. Examine the physical properties of such carbonates as are available. What ones are soluble in water (p. 275 of text)? Test the action of hydrochloric acid or sulfuric acid on each by adding 1 or 2 drops of the acid to 0.1 g. of the carbonate on a watch glass. What evidences have you that a gas is evolved? Arrange a simple apparatus to determine whether or not the gas evolved is carbon dioxide, then test one or more of the carbonates.

All carbonates when treated with hydrochloric acid or sulfuric acid evolve carbon dioxide. This reaction serves as a good test for carbonates.

Can you suggest any reason why carbon dioxide is so readily liberated from carbonates?

EXERCISE 49

A STUDY OF CARBON MONOXIDE (Optional)

Apparatus. Flask and bottles arranged as shown in Fig. 38 (*A* is a 250-cc. flask, and the bottles are all 250-cc. wide-mouthed); *E* is a hard-glass tube from 12 to 15 cm. long.

Materials. 50 cc. sodium hydroxide solution; 100 cc. limewater (R.S.); 2 g. copper oxide; 8 g. oxalic acid; sulfuric acid; wooden splints.

Precaution. *Carbon monoxide is a nearly odorless and very poisonous gas. All of the experiments must be performed in the hood. After the gas is generated, pour the contents of the generator flask into a sink or jar in the hood.*

(Two students may work together.) Arrange an apparatus according to Fig. 38. *B* contains a solution of sodium hydroxide, and *C* and *D* solutions of limewater. The tube *E*

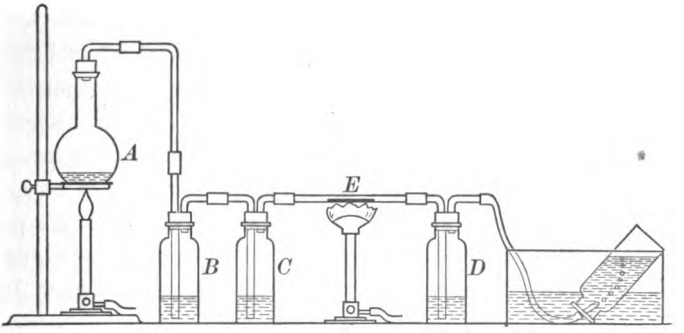


Fig. 38

contains near its middle a layer of 1 or 2 g. of copper oxide. *The whole apparatus must be air-tight. After the apparatus has been approved by the assistant,* put 7 or 8 g. of oxalic acid

($C_2H_2O_4$) into the flask *A* and pour over this 25 cc. of sulfuric acid. Stopper the flask tightly and apply a very gentle heat, at the same time heating the copper oxide in *E*. Regulate the heat so as to cause the evolved gas to bubble *slowly* through *B* and *C*. Collect over water any gas escaping from *D*. What evidences have you that the oxide is reduced? Finally, withdraw the heat from *A* and at once remove the stoppers from *A*, *B*, and *C*, and test with a burning splint the gas inclosed in each. Account for the results. Also test with a burning splint the gas which escaped from *D* and account for the result. Why is the gas passed through a solution of sodium hydroxide? Write the equations for the reactions which take place in *A*, *B*, *C*, *D*, *E*.

EXERCISE 50

A STUDY OF SOME OF THE HYDROCARBONS

Apparatus. Evaporating-dish; burner; hard-glass tube fitted with a cork and a delivery tube, as shown in Fig. 13; two 250-cc. bottles; pneumatic trough; watch glass; beaker; stirring-rod.

Materials. 15 g. soda lime (mixture of sodium hydroxide and calcium hydroxide); 10 g. fused sodium acetate; iron wire; bit of calcium carbide (size of a bean); wooden splints; 3 cc. each of gasoline and kerosene.

a. *Methane.* Intimately mix, by grinding together in a mortar, 15 g. of soda lime and 10 g. of fused sodium acetate. Transfer the mixture to the hard-glass tube used in preparing oxygen and proceed just as in the preparation of oxygen, except that the tube should be clamped in a horizontal position while being heated. Collect over water one or two bottles of the evolved gas. Note the color and odor of the gas. Is it inflammable?

Sodium acetate has the formula $NaC_2H_3O_2$. When heated with the sodium hydroxide, methane is generated according to the following reaction:

$$NaC_2H_3O_2 + NaOH \longrightarrow Na_2CO_3 + CH_4$$

b. *Acetylene.* Nearly fill a test tube with water and drop into it a small piece of calcium carbide. Note the gas evolved (R). Ascertain by holding a lighted splint at the mouth of the tube whether the gas is inflammable.

c. Obtain from the instructor a few drops each of gasoline and of kerosene. Test the inflammability of each by dipping the end of a glass rod in the liquid and then touching it to the tip of a flame. Place 10 drops of gasoline on a watch glass (hood) and set the glass on a beaker half filled with boiling water. Note the time required for its complete evaporation. Repeat the experiment, using 10 drops of kerosene. Which of the two substances is the more volatile?

d. Pour 2 or 3 drops of gasoline into a warm 250-cc. wide-mouthed bottle. Cork the bottle and shake it vigorously. Now remove the cork and, standing at arm's length, bring a lighted splint to the mouth of the bottle (?). What use is suggested by the property noted in this experiment (?).

EXERCISE 51

A STUDY OF THE FLAME

Apparatus. Burner; wire gauze; porcelain dish; glass tube 15 cm. long.
Materials. Charcoal (size of a bean); wooden splint; 5 cc. limewater (R.S.); piece of white cardboard about 12 cm. square; candle.

a. Note and account for the difference between the combustion of a wooden splint and that of a piece of charcoal. What are the conditions necessary for the production of a flame? Light a candle and place it so that the flame is against a black background and is not disturbed by air drafts; then note the different cones in the flame. Test the relative temperatures of different parts of the flame by means of narrow strips of splints. Draw a diagram showing the different parts of the flame. Extinguish the candle flame and hold a lighted splint 2 or 3 cm. from the wick in the little column of smoke (?).

b. What two elements constitute the main parts of ordinary fuels? What products form when these elements burn in air or oxygen? Devise simple experiments to show the presence of these products in the gases evolved by the burning candle.

c. What is meant by the kindling temperature of gases? Press a piece of wire gauze halfway down on a Bunsen flame. Notice that the flame does not extend above the gauze. Is this due to the absence there of combustible gases? Test for their presence by means of a lighted splint.

Turn off the gas, then turn it on and ignite it over a piece of wire gauze held horizontally 4 or 5 cm. above the top of the burner. Note the results and explain. How does the miner's safety lamp prevent explosions?

Hold a porcelain dish in a small luminous Bunsen flame. Account for the deposition of carbon (lampblack). Does the nonluminous flame deposit carbon? To what is the luminosity of the flame due?

d. Hold a splint horizontally in the base of the Bunsen flame for two or three seconds and note the results. In the same way determine the relative temperatures of various parts of the flame.

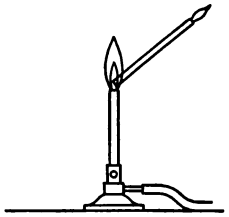


FIG. 39

Turn the gas down until the flame is 7 or 8 cm. in height, then quickly thrust *vertically* through the center of the flame a piece of white cardboard, the lower end resting against the top of the burner. Remove the cardboard before it is ignited and note from the scorched portions the relative temperatures of different parts of the flame. Draw a diagram to illustrate your results.

That the center of the base of the flame contains the unburned gas may be shown by holding in it the end of an inclined glass tube (Fig. 39) and igniting the gas at the upper end of the tube.

EXERCISE 52

THE SUGARS

Apparatus. 3 test tubes; 2 small beakers; stirring-rod; burner.

Materials. 3.5 g. copper sulfate crystals dissolved in 50 cc. water (label this solution "A"); 17.5 g. sodium potassium tartrate (Rochelle salts) dissolved in 50 cc. sodium hydroxide solution (desk; label this solution "B"; these solutions should be poured into bottles and reserved for future exercises); 5 cc. commercial glucose or Karo corn sirup; 2 g. sucrose; 1 g. each of sweets such as candy, honey, molasses; 2 or 3 g. sodium carbonate dissolved in as little water as possible; red litmus paper; hydrochloric acid.

a. The test for dextrose. The most common test for dextrose is the reaction with Fehling's solution. This is prepared as needed by mixing equal volumes of solutions A and B, prepared as directed above.

Pour into a test tube about 3 cc. each of solutions A and B. When thoroughly mixed, the resulting solution should be deep blue, but perfectly clear. Heat the blue solution nearly to boiling, add 1 or 2 drops of commercial glucose (Karo corn sirup will do as well) and continue the heating for a few moments. The copper sulfate in the solution is reduced to cuprous oxide by the dextrose, and this separates in the form of a red or yellow solid. Levulose will act in the same way. Dissolve samples of candy, honey, and molasses in a little water and test for the presence of dextrose and levulose in these sweets.

b. The action of cane sugar on Fehling's solution. In a similar way try the action of cane sugar on Fehling's solution. Note that the pure sugar does not reduce the solution.

Now dissolve about 1 g. of the sugar in 10 cc. of water. Add 4 or 5 drops of concentrated hydrochloric acid and slowly heat nearly to boiling. Set the solution aside for about five minutes, then cool and neutralize the acid present by

adding a concentrated solution of sodium carbonate until the resulting mixture is just alkaline to litmus paper. Now test this with Fehling's solution as in *a*. Account for the result.

EXERCISE 53

A STUDY OF STARCH

Apparatus. 200-cc. beaker; stirring-rod; ring stand and burner; 3 test tubes.

Materials. Iodine solution prepared by dissolving 0.5 g. iodine and 2.5 g. potassium iodide in 25 cc. water (label this "Iodine Solution" and preserve for use in a number of exercises); 0.1 g. flour; 10 g. starch; piece of bread; hydrochloric acid; 3 g. sodium carbonate dissolved in a little water; red litmus paper; starch solution (R. S.); Fehling's solution.

a. Microscopic appearance. If a microscope is available, examine the appearance of starch from different sources (corn, wheat) when magnified. Draw diagrams of the starch granules.

b. Action of acids on starch. Try the action of starch solution on Fehling's solution (as in Exercise 52) (?).

Add 2 cc. of hydrochloric acid to 50 cc. of starch solution, cover the beaker with a watch glass, and boil the contents gently for thirty minutes, allowing the solution to concentrate to about 25 cc. Cool the liquid, neutralize the acid with a concentrated solution of sodium carbonate, and again test the solution with Fehling's solution (?).

c. Test for starch. Recall the action of iodine on starch (Exercise 42). This constitutes a good test for starch.

Test different foods (such as bread, potatoes, and corn meal) for starch. To do this, boil from 5 to 10 g. of the food with 100 cc. of water, stirring the mass thoroughly so as to break it into small pieces; then filter it and cool the filtrate. Now stir the filtrate with a glass rod, the end of which is first dipped into a solution of iodine (?).

**d. The action of heat on starch.* Place 3 or 4 g. of starch in a test tube and heat *slightly* for ten or fifteen minutes, regulating

the heat so as not to burn the starch (the same results may be obtained by heating a piece of bread in an oven until it is dry and crisp). How does the product differ in taste from the original starch? The heat changes a part of the starch into an isomeric compound known as *dextrin*. This is sweet and dissolves in water, forming a mucilage-like solution which is used on the back of postage stamps and for other similar purposes.

EXERCISE 54

A STUDY OF TEXTILE FIBERS

Apparatus. 4 small beakers or test tubes; stirring-rod; burner; evaporating-dish; 2 large beakers.

Materials. 3 strips each of uncolored cotton, wool, silk, and linen cloth (3 cm. × 15 cm.); 50 cc. of sodium hydroxide solution; strip of filter paper; 3 strips of filter paper (2 cm. × 10 cm.); ammonium hydroxide; hydrochloric acid; sulfuric acid.

a. Effect of heat upon textile fibers. Ignite the end of a strip of cotton cloth in a Bunsen flame; then withdraw from the flame. Note the odor of the burning cloth. Does the cloth when ignited continue to burn?

Repeat, using strips of wool, silk, and linen. Can you distinguish in this way between vegetable fibers (cotton, linen) and animal fibers (wool, silk)?

b. How to distinguish between vegetable fibers (cotton, linen) and animal fibers (wool, silk). Place a strip of each kind of cloth in small beakers, cover the cloth with sodium hydroxide solution, and boil the liquid for ten minutes, replacing the water as it evaporates (the cloth must always be completely covered with the liquid); then set the beakers aside until cool (?).

c. How to distinguish between the animal fibers. Immerse strips of silk and wool in concentrated hydrochloric acid and note the change after they have stood a few minutes (?).

d. How to distinguish between the vegetable fibers. Immerse strips of cotton and linen in concentrated sulfuric acid for two minutes (?).

e. Microscopic appearance of textile fibers. If a microscope is available, examine the appearance of each kind of fiber when magnified. Compare with the diagrams on page 226 of text.

**f. Parchment paper.* Pour 20 cc. of sulfuric acid slowly and with constant stirring into a beaker containing 10 cc. of water. Pour the solution into an evaporating-dish and allow to cool. Draw strips of filter paper through the acid and then immerse them in a large beaker of water. Finally, wash the strips in a large beaker of water containing 2 or 3 drops of ammonium hydroxide.

When the strips are dry, compare their properties with those of the untreated paper.

EXERCISE 55

THE PREPARATION AND PROPERTIES OF COMMON ALCOHOL (ETHYL ALCOHOL)

Apparatus. One 2000-cc. flask (or bottle) connected with tube and bottle, as shown in Fig. 40; test tube; stirring-rod; apparatus shown in Fig. 25; evaporating-dish.

Materials. 200 g. molasses or Karo corn sirup; cake of yeast; 50 cc. limewater (R.S.); 25 cc. alcohol; small amounts (size of a pea) of sugar, starch, salt; 1 cc. cottonseed oil; iodine solution prepared in Exercise 53; sodium hydroxide solution; soda lime sufficient to fill tube *C* (Fig. 40).

a. Preparation of alcohol. (It is suggested that this experiment be performed by the instructor or by students selected by the instructor; after the alcohol is generated the liquid may be divided among the different members of the class who will then test for the alcohol as directed in *d.*)

Dissolve about 200 g. of ordinary molasses in 2000 cc. of water in the flask *A* (Fig. 40). Grind a cake of yeast with a little water and add it to the solution in *A*. Connect the

flask as shown in the figure (the bottle *B* contains limewater and the tube *C* contains soda lime). Set the apparatus aside in a warm place (30° is best) for two or three days. Note that a gas is evolved in *A* and bubbles through the limewater in *B* (?). (The students will continue with succeeding exercises, returning later to complete Experiments *b*, *c*, and *d*.)

b. Properties of alcohol. Determine the boiling point of alcohol, using the apparatus shown in Fig. 25 (?).

Pour a few drops of alcohol into an evaporating-dish, ignite, and note the characteristics of the flame.

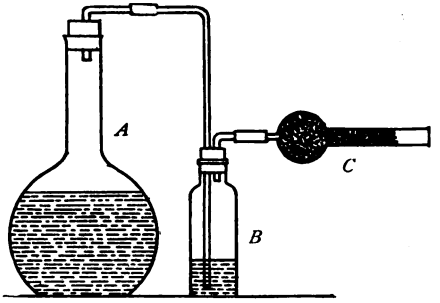


FIG. 40

Determine whether alcohol is a good solvent for (1) sugar; (2) salt; (3) starch; (4) oils, such as cottonseed oil (?).

c. Test for alcohol. Pour 2 cc. of alcohol into a test tube and add to this 5 cc. of iodine solution. Now add a solution of sodium hydroxide *one* drop at a time (mix after the addition of each drop) until the iodine color vanishes; then warm gently and set aside for a few minutes. A yellow precipitate of *iodoform* (p. 207 of text), of characteristic odor, forms. (If the amount of alcohol present is small, the iodoform may not separate, but its presence will be revealed by its odor.)

d. Divide the liquid in *A* (Fig. 40) so that each student or group of students will have from 150 to 200 cc. Pour the liquid into a flask and distill over (Exercise 11) 3 or 4 cc. Dip the end of a glass rod in the distillate and touch it to the edge of a flame (?). Test the remainder of the filtrate for alcohol as in *c*, above.

EXERCISE 56

THE DETERMINATION OF THE AMOUNT OF ALCOHOL PRESENT IN AN ALCOHOLIC LIQUID (QUANTITATIVE)

(OPTIONAL)

Apparatus. Flask and condenser connected as is shown in Fig. 41 (*A* is a 250-cc. flask, and *C* a flask which holds 100 cc. when filled to a point marked on its neck (a graduated cylinder may be used in its place)); ring stand and burner; hydrometer reading from 0.900 to 1.000; cylinder.

Materials. 100 cc. each of alcoholic liquors such as hard cider, beer, wine, alcoholic medicines.

The method commonly used is based on the fact that the specific gravity of an aqueous solution of alcohol varies according to the percentage of alcohol present. Tables have been worked out with great care, giving the specific gravities of solutions of alcohol of various strengths. If we know the specific gravity of an aqueous solution of alcohol, therefore, it is only necessary to refer to the table and read the percentage of alcohol. These tables are calculated for certain temperatures, so that in determining the specific gravity of the alcohol care must be taken that the temperature of the solution is the same as that indicated in the tables used. These tables are given in Allyn's "Elementary Applied Chemistry" (pp. 66–75), also in *Bulletin 107*, United States Department of Agriculture.

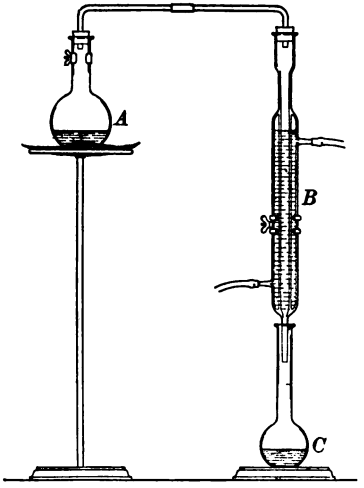


FIG. 41

Pour exactly 100 cc. of any alcoholic liquid into a flask *A* (Fig. 41) and distill over about 50 cc., collecting the distillate in the 100-cc. flask, as shown in the figure. Since alcohol is quite volatile (boiling point 78.3°), all of the alcohol present in the 100 cc. of liquid will be contained in the 50 cc. of the distillate. Now dilute the distillate to exactly 100 cc., mix thoroughly, pour into a cylinder, and having brought it to the proper temperature, determine its specific gravity by means of a hydrometer. Refer to the tables for the percentage of alcohol present in the distillate. Why is it necessary to distill the liquid? Why dilute the distillate to 100 cc. before taking the specific gravity?

EXERCISE 57

THE ACTION OF PRESERVATIVES (OPTIONAL)

Apparatus. Two 250-cc. bottles or beakers; 500-cc. beaker; 2 test tubes; ring stand and burner.

Materials. 300 cc. sweet milk; drop of formalin; 10 cc. hydrochloric acid to which is added 1 drop of a solution of ferric chloride (R.S.); 1 g. sodium benzoate.

a. The action of formaldehyde on milk. Thoroughly clean two small bottles with hot water and half fill each with sweet milk. Add to the milk in one of the bottles a drop of formalin and mix thoroughly. Now pour about 5 cc. of milk from each of the two bottles into separate test tubes; add to each an equal volume of concentrated hydrochloric acid to which has been added just a trace of ferric chloride solution (the ordinary commercial hydrochloric acid serves the purpose well, since it usually contains a trace of ferric chloride as an impurity).

Mix the contents of each of the tubes thoroughly and set them in a beaker of boiling water. Note any change in color. How can you detect the presence of formaldehyde in milk?

Set the two bottles containing the remainder of the milk aside and examine from time to time, noting when the milk in each becomes sour.

b. The action of sodium benzoate on sweet cider or grape juice. The student may likewise study the action of sodium benzoate in preventing the fermentation of sweet cider or grape juice. In such cases the weight of the preservative added to the beverage should be from 0.1 to 0.2 per cent of the weight of the beverage.

The use of formaldehyde is no longer permitted by the federal laws, since it is a poison. The use of sodium benzoate is permitted in certain foods. Do you see any reason why the federal law should prohibit entirely the use of preservatives in milk but permit the use of sodium benzoate in certain foods, such as jams and catchup?

EXERCISE 58

A STUDY OF VINEGAR (QUANTITATIVE) (OPTIONAL)

Apparatus. Evaporating-dish; beaker; ring stand and burner; burette.

Materials. 30 cc. of different kinds of vinegars; 1 cc. phenolphthalein solution (R.S.); 3 cc. sodium hydroxide solution diluted to 100 cc. with water.

a. Determination of the solids in vinegar (quantitative). Weigh a small evaporating-dish and pour into it a definite volume (say 25 cc.) of vinegar. Evaporate the vinegar to complete dryness (Fig. 32) and carefully wipe the bottom of the dish with a dry towel. Weigh it once more.

From your results calculate the amount of solid matter in 100 cc. of the vinegar. Pure cider vinegar should contain not less than 1.6 g. of solids in 100 cc. of vinegar (this is the limit fixed by the federal government as well as by the statutes of many of the individual states).

Note the odor and taste of the solid matter obtained from the vinegar. The solids from pure cider vinegar should have an odor and taste suggestive of baked apples. Other kinds of

vinegar may be tested in the same way. The character of the solids varies according to the source of the vinegar.

b. Determination of the acidity of vinegar. Introduce exactly 5 cc. of vinegar into a small beaker and dilute it with about 50 cc. of water. Add 2 drops of a solution of phenolphthalein and then run in from a burette a solution of sodium hydroxide, until the solution is neutral, as in Exercise 23.

If a solution of sodium hydroxide of known concentration is used, it is evident that one may in this way determine the amount of acetic acid in the vinegar. The federal law requires that vinegar must contain not less than 4 g. of acetic acid in 100 cc. of the vinegar.

EXERCISE 59

THE PREPARATION OF A SIMPLE ESTER

Apparatus. 250-cc. flask; ring stand and burner; test tube.
Materials. Acetic acid (R.S.); alcohol (R.S.); sulfuric acid.

Preparation of ethyl acetate. What is an ester? Ethyl acetate is an ester derived from acetic acid by replacing an atom of hydrogen in the acid by the univalent radical *ethyl* (C_2H_5) and has the formula $C_2H_5C_2H_3O_2$. It is a colorless liquid boiling at 78° and having a characteristic fragrant odor.

Pour into a small flask 10 cc. of acetic acid (or of a saturated solution of sodium acetate), 5 cc. of sulfuric acid, and 3 cc. of alcohol. Mix well and heat slightly. Ethyl acetate is formed and may be recognized by its odor. Do not mistake the odor of the vapor of alcohol for that of ethyl acetate (warm a little alcohol in a test tube and note the difference between its odor and that of ethyl acetate). The equation for the reaction is

$$H \cdot C_2H_3O_2 + C_2H_5OH \longrightarrow C_2H_5C_2H_3O_2 + H_2O$$

The sulfuric acid is added to absorb the water formed.

This reaction serves as a test for both acetic acid and acetates.

EXERCISE 60

TESTS FOR FATS AND PROTEINS

Apparatus. Stirring-rod; evaporating-dish; 2 beakers; ring stand and burner.

Materials. 1 or 2 drops of cottonseed oil; melted lard or butter; bit of cheese; alcohol (R.S.); carbon tetrachloride (R.S.); small portion of white of egg; 25 cc. milk; nitric acid; ammonium hydroxide; 1 g. flour.

a. Fats. Rub in different places on a piece of white paper 1 drop of various fats, such as cottonseed oil, cream, melted lard, and butter. Note the appearance of the spot when held in front of a light (?). Heat the paper slightly to see if the spot will disappear (?). Test different samples of cheese (melt a small piece and rub on paper) and milk for fats by this method.

Test the solubility of each of the fats (1) in alcohol, (2) in carbon tetrachloride.

b. Proteins. Place a small portion of the white of an egg (protein) in a test tube and heat it by dipping the tube into boiling water (?).

Pour 20 cc. of milk into an evaporating-dish and heat gently. Note the scum that collects on the surface. Remove the scum with a glass rod, collect other portions of the scum in the same way, and save for further tests.

Transfer a portion of the coagulated white of egg to a small beaker and moisten it with 2 or 3 drops of nitric acid (?). Wash the egg free from acid with repeated portions of water, then moisten it with ammonium hydroxide (?).

In the same way test for the presence of protein in the scum which separated when the milk was heated. Test other substances for protein, such as flour, woolen cloth, a clipping of a finger nail (?). Nitric acid stains the skin yellow (?).

Burn a small bit of different kinds of protein, such as egg, hair, the scum of milk (?).

EXERCISE 61

THE COMPOSITION OF FLOUR

Apparatus. Beaker (500-cc.); ring stand and burner; porcelain crucible; pipe-stem triangle.

Materials. 50 g. flour; iodine solution prepared in Exercise 53 for testing for starch; cheesecloth (from 12 to 15 cm. square); carbon tetrachloride (R.S.).

a. Weigh out about 25 g. of flour and mix with just enough water to form a stiff dough, working it in the hands until it becomes smooth and elastic. Place the dough on a piece of cheesecloth, then fold the cloth about the dough and tie it with a string so as to form a little bag. Nearly fill your largest beaker with water, immerse the bag and contents in the water, and repeatedly squeeze the bag between the fingers. Note that the water becomes cloudy. Retain a portion of this cloudy liquid for further tests (see ***b***, below).

Continue the washing in fresh portions of water until the resulting wash water remains clear. The action may be hastened by working the dough in a small stream of running water. Test for protein the residue remaining in the cloth (?). The substance is known as *gluten*; burn a portion of the gluten (?).

b. Test separate portions of the cloudy liquid reserved in ***a***, for starch (Exercise 53) and for sugar (Exercise 52) (?).

c. Fill a test tube about one-fourth full of flour, add carbon tetrachloride until the tube is half filled, and shake the contents vigorously. Set the tube aside until the flour settles, then pour off the clear liquid, evaporate it (Fig. 3), and test the residue, if any, for fat (?).

d. Place about 0.1 g. of flour in a porcelain crucible; heat it with the Bunsen flame (Fig. 2); gradually increase the heat until only a white residue remains (?).

EXERCISE 62

SOME FURTHER EXPERIMENTS WITH MILK (Optional)

Apparatus. Evaporating-dish; stirring-rods; ring stand and burner; 2 beakers.

Materials. 150 cc. milk; acetic acid (R.S.); Fehling's solution; one-half junket tablet (these tablets may ordinarily be obtained from any druggist; they may always be had at very little cost by addressing Chr. Hansen's Laboratory, Little Falls, New York).

a. Determination of the solids and the water in milk. Place a short stirring-rod in a small evaporating-dish and accurately weigh the two together. Introduce about 20 cc. of milk and again weigh. Now evaporate the milk to dryness (Fig. 31), occasionally stirring it with the rod to break the scum (?) which would otherwise retard evaporation. (While the evaporation is taking place proceed with *b.*)

When the residue is perfectly dry, carefully wipe the outside of the dish, cool, and reweigh. From your results calculate the percentages of solids and water in the milk. (Pure milk contains not less than 12 per cent of solid matter. Consult your state laws as to the minimum amount of solid matter allowed in milk sold in the state.)

b. The separation of the protein (casein) in milk by rennin. Dissolve about one half of a so-called "junket" tablet in a little cold water and add the solution to about 100 cc. of sweet milk heated until just lukewarm. Stir the solution, then cool it and set it aside until the rennin contained in the tablet causes the separation of the curd (casein). Break up the curd by stirring, and filter it. Save the filtrate for further tests.

c. The separation of the protein in milk by acid. Add 1 or 2 drops of acetic acid (vinegar will serve) to 5 cc. of milk, mix thoroughly, and set aside (?). The presence of an acid causes the casein to separate (hence the appearance of sour milk).

d. The separation of the lactose in milk. Evaporate the filtrate reserved in *b*, refiltering it if more solid matter separates. Taste the residue (?). Test it with Fehling's solution (Exercise 52) (?).

EXERCISE 63

METHODS FOR DISTINGUISHING BETWEEN BUTTER AND OLEOMARGARINE (OPTIONAL)

Apparatus. Iron spoon; burner; wooden splint (match stick will do); 100-cc. beaker.

Materials. 10 g. each of fresh butter and oleomargarine (also process butter, if available); 50 cc. sweet milk.

a. Foam test. Heat gently over a small flame from 2 to 3 g. of the sample (butter or oleomargarine) in a spoon. Under these conditions butter will melt without sputtering and with the formation of much foam on the surface, while oleomargarine will sputter and give but little foam. Process, or renovated, butter (rancid butter which has been purified by melting the fat, skimming it off the surface, and churning it with milk under certain conditions) acts like oleomargarine.

b. Sweet-milk test. Pour 50 cc. of sweet milk into a small beaker and heat nearly to boiling. Add to the hot milk 4 or 5 g. of the sample and stir it with a wooden splint until the fat is melted, then place the beaker in ice water and continue the stirring until the fat solidifies. Under these conditions butter will solidify in the form of granules which mix with the milk. Oleomargarine, on the other hand, will collect in a single mass so that it can be removed from the milk in one lump with the wood stirrer.

EXERCISE 64

PHOSPHORUS AND ITS COMPOUNDS

Apparatus. 250-cc. wide-mouthed bottle; deflagrating-spoon; glass plate; small beaker.

Materials. Phosphorus (size of a pea); litmus paper (red and blue); 10 cc. ammonium molybdate solution (R.S.); ammonium hydroxide; nitric acid.

Cover the bottom of a wide-mouthed bottle (250-cc.) with water to a depth of about 1 cm. Place a piece of phosphorus on a deflagrating-spoon and ignite it by touching it with a hot wire. Quickly lower the phosphorus into the bottle and cover the mouth of the bottle with a glass plate. When the phosphorus ceases to burn, withdraw the spoon and allow the fumes in the bottle to dissolve in the water. Test the solution with litmus paper. What is present in the water?

Pour the solution into a small beaker, add 2 or 3 cc. of nitric acid, and boil the solution until about half of it evaporates. The nitric acid oxidizes to phosphoric acid all the phosphorus compounds present. Add a few drops of the solution to 10 cc. of a solution of ammonium molybdate and warm gently. Note the result (the compound formed has a very complex composition). Add ammonium hydroxide to the mixture until the liquid is alkaline. Note the result. Again acidify the liquid with nitric acid. Note the result. *The formation of a yellow precipitate upon the addition of ammonium molybdate, which precipitate is insoluble in nitric acid and soluble in ammonium hydroxide, serves as a good test for phosphoric acid and its salts.*

EXERCISE 65

ARSENIC AND SOME OF ITS COMPOUNDS

Apparatus. Blowpipe; piece of charcoal (2 cm. × 8 cm.); hard-glass tube (10 cm. long and 6 or 7 mm. wide); file; burner.

Materials. Arsenic (size of a grain of wheat); 0.1 g. arsenious oxide.

a. Note the physical properties of arsenic. Place a bit of the arsenic in a cavity on a piece of charcoal and gently heat it (hood), using a blowpipe. Note the peculiar, garliclike odor (poisonous).

b. Introduce into a hard-glass tube an amount of arsenious oxide equal in bulk to a grain of wheat. Cover this to a depth of 2 or 3 cm. with somewhat finely powdered charcoal which has been previously heated to a high temperature in a porcelain crucible. See that the inner surface of the tube above the charcoal is perfectly clean.

Incline the tube and heat the *upper* portion of the charcoal to a high temperature, then, while maintaining the charcoal at this temperature, gradually bring the lower part of the tube also into the flame. The upper part of the tube must be kept as cool as possible. The arsenious oxide is changed into a vapor, which passes over the hot charcoal. Account for the result (R).

Cut the tube as near the bottom as possible and remove the charcoal, then, inclining the tube, apply a very *gentle* heat to that portion of it which contains the coating. Note that small white crystals are slowly deposited in the colder portions of the tube (R). Examine these with a magnifying-glass. Note their form.

EXERCISE 66

A STUDY OF SOME OF THE PROPERTIES OF ANTIMONY

Apparatus. Blowpipe; beaker; stirring-rod; hydrogen sulfide generator (Fig. 33).

Materials. Piece of charcoal (2 cm. × 8 cm.); 2 pieces of antimony (size of a grain of wheat); hydrochloric acid; nitric acid; strip of zinc; 10 g. ferrous sulfide.

a. Heat a bit of antimony on charcoal as in *a*, Exercise 65. The product is Sb_2O_3.

**b.* Introduce into a test tube a bit of antimony no larger than a grain of wheat and add about 3 cc. of hydrochloric acid and then 2 or 3 drops of nitric acid. After the metal has dissolved, pour the solution into 50 cc. of water. If a precipitate forms, add hydrochloric acid, drop by drop, with constant stirring, until the precipitate dissolves. Half fill a test tube with the resulting solution and insert a strip of zinc. Note the results (compare Exercise 24). Through the remainder of the solution pass a few bubbles of hydrogen sulfide. The product is Sb_2S_3. Note its properties.

EXERCISE 67

A STUDY OF SOME OF THE PROPERTIES OF BISMUTH

Apparatus. Blowpipe; beaker; stirring-rod; hydrogen sulfide generator (Fig. 33).

Materials. 2 pieces of bismuth (size of a grain of wheat); piece of charcoal (2 cm. × 8 cm.); nitric acid; 10 g. ferrous sulfide; hydrochloric acid.

a. Heat a piece of bismuth on charcoal, as in the case of antimony (Exercise 66). Bi_2O_3 is formed and is deposited on the charcoal. Contrast the effect of heating arsenic, antimony, and bismuth in air.

*b. Repeat a, Exercise 66, substituting bismuth for antimony and using nitric acid alone as the solvent. The precipitate formed by hydrogen sulfide is Bi_2S_3. Note its properties.

$Bi(NO_3)_3$ is formed when bismuth is dissolved in nitric acid. Upon pouring this into water the following reaction takes place:

$$Bi(NO_3)_3 + 2\,H_2O \longrightarrow Bi\begin{matrix}OH\\OH\\NO_3\end{matrix} \longrightarrow BiONO_3 + H_2O$$

The bismuth subnitrate ($BiONO_3$) is insoluble and separates as a white solid. Upon the addition of nitric acid, a drop at a time, the reaction is reversed, $Bi(NO_3)_3$ being formed, which dissolves in the liquid.

c. Define the terms *hydrolysis* and *basic salt* and illustrate with examples from this exercise.

EXERCISE 68

COMPOUNDS OF SILICON

Apparatus. Evaporating-dish; ring stand; burner.

Materials. 2 cc. water glass (solution of Na_2SiO_3); hydrochloric acid.

a. Recall the formulas and names of the important acids of silicon.

b. Place 2 cc. of a solution of water glass (Na_2SiO_3) in an evaporating-dish, dilute with 10 cc. of water, and add 2 or 3 cc. of hydrochloric acid. Note the gelatinous precipitate (R). Evaporate to dryness and heat the dish gently with the bare flame (?). When cool, add water, filter, and examine the residue. What is it?

c. Recall the action of hydrofluoric acid on silica (R).

EXERCISE 69

COMPOUNDS OF BORON

Apparatus. Platinum wire (piece 10 cm. long, fused in glass tube for handle (Fig. 143, p. 289 of text)); burner; beaker; porcelain crucible; stirring-rod.

Materials. 8 g. borax; litmus paper (red and blue); sulfuric acid; alcohol (R.S.); 1 or 2 drops cobalt nitrate solution (R.S.).

a. Write the names and formulas for three important compounds of boron.

b. Make a little loop on the end of a platinum wire and heat it to redness in a Bunsen flame, then quickly bring the loop in contact with some borax and reheat. The borax adhering to the loop will swell up (owing to the expulsion of the water of hydration) and finally form a clear, glassy bead. Note the color imparted to the flame.

Dip the bead into a few drops of sulfuric acid and again touch it to the edge of the flame. Note the result (see *c*, below, for explanation). This serves as a simple test for borax.

Moisten the bead with a drop of a solution of a cobalt compound and reheat until the bead is transparent when cold. Note the color of the bead now. This property serves as a simple test for cobalt. (Some of the other metals likewise impart characteristic colors to the bead (see Exercise 101)).

c. Dissolve 5 g. of borax in 15 cc. of boiling water. Test the solution with litmus paper. Explain. Carefully add to the hot solution 2 or 3 cc. of sulfuric acid and stir. Cool the solution and filter off the precipitate. Compare the precipitate with borax, first, as to solubility in alcohol, and second, as to the color imparted to a flame when a small portion on a platinum wire is held in the flame.

**d.* Dry a little of the boric acid prepared in *c*, transfer to a porcelain crucible, and heat until a clear liquid is formed (?).

EXERCISE 70

GENERAL METHODS FOR THE PREPARATION OF THE COMPOUNDS OF THE METALS

Apparatus. 6 test tubes.

Materials. 0.1 g. of each of the following salts, dissolved in 5 cc. water: (1) calcium chloride, (2) lead nitrate, (3) barium chloride, (4) ferric chloride, (5) silver nitrate (solutions of any of these on the reagent shelf may be used); ammonium carbonate solution (R. S.); 0.1 g. potassium iodide dissolved in 5 cc. water; hydrochloric acid.

a. *By the direct union of the elements.* Recall the formation of sulfides of copper and of iron (Exercise 31); of chlorides of copper and antimony (Exercise 38). Write the equations for the reactions involved.

b. *By dissolving a metal or its hydroxide in appropriate acids.* Recall the formation of zinc sulfate (Exercise 8); of sodium chloride (Exercise 22); of copper nitrate (Exercise 27). Write the equations for the reactions. When a metal or its hydroxide is acted upon by an acid, what becomes of the metal?

c. *By acting upon a salt of an acid with an acid having a higher boiling point.* Recall the action of sulfuric acid upon sodium nitrate (Exercise 27); of hydrochloric acid upon iron sulfide (Exercise 32); of sulfuric acid upon fluorides (Exercise 37); of sulfuric acid on chlorides (Exercise 39); of hydrochloric acid on carbonates (Exercise 47). Write the equations for each reaction and show in what respects they are all similar.

d. *By the decomposition of a compound.* Recall the action of heat upon potassium chlorate (Exercise 6); upon copper nitrate and lead nitrate (Exercise 28). Write the equations for the reactions involved.

e. The following compounds are insoluble (see Appendix, Table of Solubility of Various Solids): calcium carbonate

($CaCO_3$), lead sulfate ($PbSO_4$), barium carbonate ($BaCO_3$), ferric hydroxide ($Fe(OH)_3$), silver chloride (AgCl), lead iodide (PbI_2). Prepare a small amount of each in a test tube (R) and state the general principle involved in each reaction.

EXERCISE 71

SODIUM AND ITS COMPOUNDS

Apparatus. Evaporating-dish; glass plate; beaker; hydrogen generator for generating carbon dioxide (Fig. 32); 250-cc. bottle; hard-glass test tube; platinum wire; burner; piece of cobalt glass (10 cm. square).

Materials. Sodium (size of a pea); litmus paper (red and blue); hydrochloric acid; 5 g. sodium chloride; 5 g. sodium carbonate; sulfuric acid; 2 or 3 crystals of Glauber's salt; 10 g. ammonium carbonate; marble for generating carbon dioxide; 3 g. sodium bicarbonate; lime-water (R.S.).

a. Recall Exercise 8, Experiment ***a.*** Cut a small piece of sodium and note the rapidity with which the freshly cut surface is tarnished. Half fill your evaporating-dish with water; then drop the sodium into this and quickly cover the dish with a glass plate (R). After the action has entirely ceased, test the liquid with red litmus paper. What compound is dissolved in the water? Convert it into common salt (R). Describe the method.

b. Dissolve 5 g. of sodium chloride in as little water as possible. Set the solution aside until some of the salt crystallizes out. Examine the shape of the crystals (use magnifying-glass) (?).

**c.* Dissolve 5 g. of sodium carbonate in 20 cc. of water. Test the solution with red and with blue litmus paper (?).

Now convert the sodium carbonate present into common salt (R). How can you be sure that the product contains no unchanged sodium carbonate? Describe the method (R). Treat some of the salt so prepared with sulfuric acid. What gas is evolved (R)?

d. Expose some clear crystals of Glauber's salt to the air and examine after one hour. The change is due to the fact that some of the water of hydration escapes. Crystals that behave in this way are said to be *efflorescent.*

**e.* Dissolve 10 g. of finely powdered ammonium carbonate in 100 cc. of cold ammonium hydroxide, shaking or stirring the mixture to secure solution. Saturate this solution with sodium chloride by shaking it with the finely pulverized salt. Pour off the clear solution into a 250-cc. bottle and pass carbon dioxide through it until a precipitate (sodium bicarbonate) forms. Filter off the precipitate, dry between two pieces of filter paper, and examine. If a precipitate does not form by the end of the laboratory period, cork the bottle, and set it aside until the next laboratory period.

f. Fill a hard-glass test tube about one-fourth full of sodium bicarbonate and heat gently. Prove that carbon dioxide is evolved. What liquid condenses in the colder part of the tube? Write equations for the reactions by which sodium carbonate is converted into the bicarbonate and vice versa.

g. Bend the end of a platinum wire into the form of a small loop and hold it in the Bunsen flame until it ceases to give any color to the flame; then dip it into a solution of a compound of sodium so that a drop of the solution is suspended in the loop; then hold it in the outer film of the base of a Bunsen flame. Note the color. Note the appearance of the sodium flame when viewed through a piece of cobalt glass.

EXERCISE 72

THE DETERMINATION OF THE WEIGHT OF COMMON SALT OBTAINED BY ADDING HYDROCHLORIC ACID TO A DEFINITE WEIGHT OF SODIUM BICARBONATE (QUANTITATIVE) (OPTIONAL)

Apparatus. Evaporating-dish and watch-glass cover; ring stand; burner; balance.

Materials. 1 g. sodium bicarbonate; hydrochloric acid.

Carefully weigh the evaporating-dish and watch glass. Transfer to the dish about 1 g. of sodium bicarbonate and reweigh. Pour 4 or 5 cc. of water on the bicarbonate, and place the watch glass on the dish so that only the lip of the dish remains uncovered. Now pour down the lip of the dish 2 or 3 drops of hydrochloric acid. Wait until the effervescence caused by the escape of the carbon dioxide ceases, then add a few drops more of the acid. Repeat until the addition of the acid no longer causes any effervescence. Now hold the watch glass in the hand just above the dish and with a little water carefully rinse back into the dish the liquid which has collected on the undersurface of it. Remove the watch glass and slowly evaporate the solution (Fig. 31).

When the solution has evaporated nearly to dryness, cover the dish with the watch glass and heat the dish with the tip of the flame. Continue the heating until there is no more liquid left in the dish or clinging to the undersurface of the glass. Then withdraw the heat and, after the dish is cool, reweigh.

From your results calculate the amount of salt formed from 1 g. of the bicarbonate. Compare your result with those obtained by other members of the class. How does the average of the results obtained compare with the theoretical results?

EXERCISE 73

THE TEST FOR POTASSIUM; THE PREPARATION OF POTASSIUM NITRATE

Apparatus. Platinum wire for flame test; cobalt glass; burner; small beaker; stirring-rod; funnel.

Materials. 0.1 g. potassium nitrate and 0.1 g. sodium chloride, each dissolved in a little water; 17 g. sodium nitrate; 15 g. potassium chloride; filter paper.

a. Test for potassium. Repeat *g*, Exercise 71, using a solution of a compound of potassium (?). Note the appearance of the flame through a piece of cobalt glass (?). Repeat, using a solution containing a compound of sodium as well as one of potassium. How could you detect both sodium and potassium if they were present in the same solution?

**b. Preparation of potassium nitrate.* Dissolve 17 g. of sodium nitrate in 15 cc. of boiling water; also 15 g. of potassium chloride in 30 cc. of boiling water. Mix the two solutions in a small beaker and evaporate (stirring the mixture) to about 20 cc.; then quickly filter the hot solution and set the filtrate (Filtrate A) aside until cold.

The reaction between potassium chloride and sodium nitrate is reversible, and the number of grams of each of the four compounds involved which dissolve in 100 g. of water at 15° and 100° is as follows:

	15°	*100°*		*15°*	*100°*
Sodium nitrate . .	84	180	Potassium nitrate .	26	247
Potassium chloride .	33	57	Sodium chloride . .	36	40

From a study of these solubilities, what compound should you expect would separate when the hot solutions of sodium nitrate and potassium chloride are mixed together? Test the solid on the filter paper. (Examine the crystals with a

magnifying-glass and compare with *b*, Exercise 71, to see if your conclusion is correct. Taste the crystals.)

What solid should you expect would separate from Filtrate A when it is cooled? Would you expect it to be pure? Examine it with a magnifying-glass. Can you detect crystals of sodium chloride in this solid?

Dissolve the solid in as little hot water as possible, cool the solution, and again filter off the solid. Repeat until no crystals of sodium chloride can be detected. Prove the identity of this compound (?).

EXERCISE 74

THE PROPERTIES OF AMMONIUM COMPOUNDS

Apparatus. Evaporating-dish and watch-glass cover; 5 test tubes; burner; hydrogen sulfide generator (Fig. 33).

Materials. Ammonium hydroxide; hydrochloric acid; sodium hydroxide solution; litmus paper (red and blue); 10 g. ferrous sulfide; 0.2 g. ferrous sulfate dissolved in 10 cc. water; ammonium carbonate (R.S.); barium chloride (R.S.); calcium chloride (R.S.); zinc acetate (R.S.).

a. Pour 10 cc. of ammonium hydroxide into an evaporating-dish, neutralize with hydrochloric acid, and evaporate to dryness on a water bath (Fig. 31) (?). Note the odor of the residue.

Introduce about one half of the residue (?) into a test tube, add a few drops of sodium hydroxide solution, and heat gently. Note the odor of the evolved gas and its action on a moist strip of red litmus paper (?). *This reaction serves as a good test for all ammonium compounds.*

Cover the evaporating-dish containing the remainder of the residue with a watch glass and heat *gently* with a *small* flame. Note that the solid *sublimes*; that is, passes directly from the solid form into a vapor which condenses (partly) on the cold surface of the watch glass. This property is characteristic of most ammonium compounds.

*b. Saturate 5 cc. of water (Fig. 33) with hydrogen sulfide and set aside; also saturate 5 cc. of ammonium hydroxide with the gas (?). Add a few drops of each of these solutions to separate portions of ferrous sulfate solution (?) (ferrous sulfide is soluble in strong acid). In general, what metals will be precipitated by ammonium sulfide and not by hydrogen sulfide?

*c. Add a few drops of ammonium carbonate solution to solutions of compounds of each of the following elements: barium, calcium, zinc (?).

EXERCISE 75

DETECTION OF COMPOUNDS OF THE ALKALI METALS

Recall such reactions of sodium, potassium, and ammonium compounds; also of carbonates, sulfates, nitrates, sulfites, sulfides, chlorides, bromides, iodides, and phosphates as will serve to identify them, and outline a method of procedure in the identification of them. Then ask the instructor for unknown compounds falling within this list and identify them.

EXERCISE 76

THE PREPARATION AND PROPERTIES OF SOAP

Apparatus. Evaporating-dish; ring stand and burner; large beaker; stirring-rod; funnel; small beaker; 4 test tubes.

Materials. Alcohol (R.S.); 5 g. cottonseed oil (or lard); 1 g. sodium hydroxide dissolved in 2 cc. water; hydrochloric acid; magnesium sulfate (R.S.); calcium chloride solution (R.S.); 1 g. sodium chloride dissolved in 5 cc. water; litmus paper (red and blue).

a. Add 10 cc. of alcohol to 5 g. of cottonseed oil in an evaporating-dish. To the resulting mixture add 1 g. of sodium hydroxide dissolved in 2 cc. of water. Evaporate carefully (use small flame and do not let the tip touch the dish),

stirring the mixture constantly until the odor of alcohol can no longer be detected. Write the equation for the reaction on the supposition that the lard is composed of palmitin. What is the process called? What remains in the dish?

b. Add 50 cc. of cold water to the residue in the dish, stir well for a few minutes, and filter. Pour 5 cc. of the filtrate into each of three test tubes. To the first add 2 or 3 drops of hydrochloric acid; to the second add a few drops of a solution of magnesium sulfate. In like manner add a few drops of a solution of calcium chloride to the third. Note what takes place in each test tube. Why do waters containing calcium and magnesium compounds (*hard waters*) not lather freely with soap?

c. Add a few drops of sodium chloride solution to 10 cc. of the filtrate obtained in *b* (?) (p. 292 of text). The soap in the filtrate prepared in *b* is not in solution but in colloidal suspension (p. 99 of text). The salt causes the precipitation of the colloid (soap).

d. Recall the effect of soap in the formation of emulsions (Exercise 19). What influence has this property upon the cleansing action of soap?

EXERCISE 77

A STUDY OF SOME OF THE COMPOUNDS OF CALCIUM

Apparatus. Evaporating-dish; ring stand and burner; watch glass; small beaker; 2 test tubes; wire gauze; glass plate; platinum wire for flame test.

Materials. Piece of lime (size of a walnut); bits of marble; hydrochloric acid; ammonium carbonate (R.S.); ammonium hydroxide; disodium phosphate (R.S.); 10 g. plaster of Paris; 0.1 g. each of the chloride or the nitrate of calcium, strontium, and barium.

a. Immerse a piece of calcium oxide (lime) as large as a walnut in a beaker of water for three or four seconds. Repeat (if necessary) until the surface of the lime remains moist

for ten seconds after the piece is withdrawn from the water; then place the piece on a watch glass and set the watch glass aside until the end of the period (?). *This is a convenient way of preparing calcium hydroxide.*

b. Dissolve 1 or 2 g. of marble in hydrochloric acid (R). What does the effervescence indicate? Evaporate the solution to dryness (use the bare flame and evaporate to complete dryness (Fig. 31)). What is the composition of the residue? Expose a small piece of it to the air for an hour and account for the results.

Dissolve the remainder of the residue in a little water and divide the liquid into two portions. To the one add a few drops of ammonium carbonate (R); to the other add a few drops of ammonium hydroxide and then of a solution of disodium phosphate. The precipitate is $Ca_3(PO_4)_2$.

c. Place a piece of marble on a wire gauze and apply a strong heat for about fifteen minutes. When cool, drop the residue into 25 cc. of water and stir. Filter, and test the filtrate with litmus paper. Then blow exhaled air through the filtrate. Explain.

**d.* Place on a glass plate a penny which has been rubbed with a drop of oil. Pour over the coin a thick paste prepared by adding water to plaster of Paris. Set the glass plate aside until the paste hardens, then remove the coin and note the result.

e. Try the flame tests for compounds of calcium, of strontium, and of barium (use the chloride or nitrate), as in *g*, Exercise 71, and note the results.

EXERCISE 78

HARD WATERS AND METHODS FOR SOFTENING THEM

Apparatus. 60-cc. bottle; carbon dioxide generator (Fig. 32); ring stand and burner; funnel; 2 test tubes; small beaker.

Materials. 30 cc. limewater (R.S.); bit of soap dissolved in water; 10 to 15 g. of marble; magnesium sulfate (R.S.); filter paper; 1 g. sodium carbonate dissolved in as little water as possible.

a. Bubble carbon dioxide into 25 cc. of limewater diluted with an equal volume of water. Note that a precipitate forms (R) which gradually dissolves as more of the gas is passed through (?). Add a few drops of a soap solution to 5 cc. of the resulting solution and note the result.

Divide the remainder of the filtrate into two parts. Gradually boil the one part and note the result. To the other part add a few drops of clear limewater, mix intimately, and note the results. Explain.

b. Shake 1 g. of calcium sulfate with 10 cc. of water in a test tube for two or three minutes; filter, and add to the filtrate 2 or 3 drops of a saturated solution of sodium carbonate (R).

All hard waters contain more or less calcium acid carbonate, calcium sulfate, calcium chloride; also the corresponding compounds of magnesium. (The methods used for removing the calcium compounds likewise serve for removing the magnesium compounds.) How could such waters be softened on a large scale? Waters softened in this way would contain what compounds in solution?

c. Test some hard waters from wells by the above methods.

EXERCISE 79

SOME ADDITIONAL EXPERIMENTS WITH SOAP (OPTIONAL)

Apparatus. Three 250-cc. bottles; burette or graduated cylinder; 2 test tubes.

Materials. 1 g. soap dissolved in 100 cc. distilled water; ordinary reagents; 0.5 g. sodium sulfate.

a. The determination of the amount of soap lost by using hard water for washing. Place three 250-cc. bottles on the desk. Into the first pour 100 cc. of *hard water* (preferably an average sample of the water used in your town or city); into the second pour 100 cc. of distilled (or rain) water; and into the third pour 100 cc. of distilled water containing 0.5 g. of sodium sulfate in solution. Now add to each the soap solution, 1 cc. at a time, and shake the bottle *vigorously.* Continue adding the soap solution until the lather formed persists for five minutes. Compare the amounts of the soap solution required in each case to produce a permanent lather (?). Does the presence of sodium sulfate prevent the formation of the lather (sodium sulfate is left in waters softened by ordinary methods) (p. 301 of text)?

It will be interesting to make at least a rough approximation of the amount of hard water used yearly in your city for washing, and then to determine the cost of the soap lost in one year, owing to the use of hard water. (Columbus, Ohio, with a population of about 200,000, now softens the water supply of the entire city, and it is estimated that the annual saving to the city in consumption of soap alone is about $300,000.)

b. The analysis of washing-powders. Devise methods for detecting the presence of the following substances if present in washing-powders: (1) sodium carbonate; (2) borax (*b*, Exercise 69); (3) mineral matter, such as sand. Test one or more washing-powders for these substances.

EXERCISE 80

THE PREPARATION AND PROPERTIES OF BLEACHING-POWDER (OPTIONAL)

Apparatus. Flask (250-cc.) and bottle (250-cc.) connected with glass tubing and bottle as shown in Fig. 42; 200-cc. beaker; stirring-rod.

Materials. 15 g. manganese dioxide; hydrochloric acid; 25 cc. of water in bottle *B*; 10 cc. of sodium hydroxide solution added to 50 cc. of water in *D*; sufficient calcium hydroxide (slaked lime) to half fill the tube *C*; strips of colored calico; sulfuric acid.

(Hood.) Generate chlorine in *A* (Fig. 42). The gas must be evolved *slowly*, for which reason only a *very gentle* heat is applied to the flask. The gas bubbles through the water in *B*,

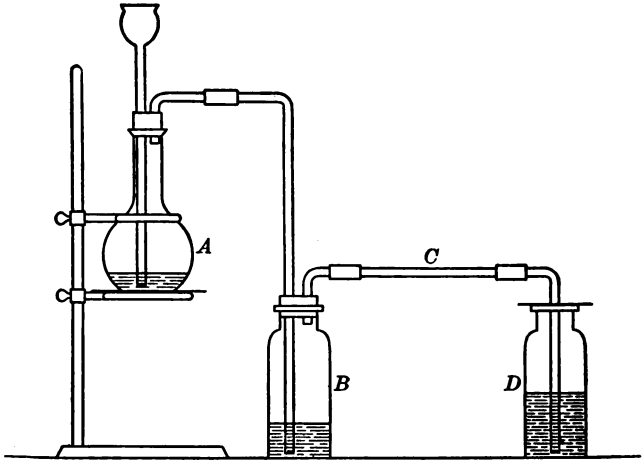


FIG. 42

then passes over the calcium hydroxide in *C*, any unabsorbed gas being caught in *D* (?).

When all of the chlorine has passed over from *A*, disconnect the apparatus and transfer the contents of the tube *C* to

a beaker and pour over it 75 cc. of water containing 1 cc. of sulfuric acid. Stir well and immerse in the mixture some strips of colored calico for a few minutes (?). Complete the following equations:

$$Ca(OH)_2 + Cl \longrightarrow$$
$$CaOCl_2 + H_2SO_4 \longrightarrow$$

EXERCISE 81

MAGNESIUM AND ITS COMPOUNDS

Apparatus. Porcelain crucible and cover; ring stand and burner; pipe-stem triangle; evaporating-dish; 2 test tubes.

Materials. Strips of magnesium 5 cm. long; small beaker; red litmus paper; 2 to 3 g. magnesium carbonate; magnesium sulfate solution (R.S.); ammonium chloride (R.S.); disodium phosphate (R.S.).

a. Wind a strip of magnesium wire into a coil and place it in a porcelain crucible. Put the cover on the crucible and apply a gentle heat. Raise the cover slightly from time to time so as to admit air. Continue until the magnesium is entirely burned, leaving a white powder. Cool, add water, and stir thoroughly; then test with litmus (?).

**b.* Convert 2 or 3 g. of magnesium carbonate into the chloride (R). Evaporate the solution to complete dryness in an evaporating-dish, heating the residue with the bare flame. When it is cool, add a few drops of water, stir, and test with litmus (?). Are waters containing magnesium chloride objectionable for use in steam boilers?

c. Pour 3 cc. of a solution of magnesium sulfate into a test tube and add an equal volume of a solution of ammonium chloride. Now add to this a few drops of a solution of disodium phosphate (Na_2HPO_4). The precipitate has the composition $MgNH_4PO_4$. What is the name of this compound? To what class of compounds does it belong? The above reaction serves as a good test for magnesium compound.

EXERCISE 82

ZINC AND ITS COMPOUNDS

Apparatus. Blowpipe; burner; pieces of charcoal; 3 test tubes; beaker.

Materials. 0.5 g. zinc; sulfuric acid; sodium hydroxide solution; ammonium sulfide (R.S.); 0.2 g. sodium carbonate dissolved in 3 cc. of water; hydrochloric acid.

a. Place a bit of zinc on charcoal and heat it in the tip of the flame of a blowpipe (R). The resulting compound is deposited as a film on the charcoal. Note the color of it. Is its color the same when hot as when cold?

b. Convert (?) a bit of zinc into zinc sulfate and test the solution of the salt with the following reagents: (1) Sodium hydroxide solution (1 drop, or just sufficient to cause a precipitate); zinc hydroxide precipitates (R), but the precipitate dissolves again if an excess of sodium hydroxide is added. (2) Ammonium sulfide (R) (note the color of the precipitate). *Zinc is the only metal which forms an insoluble white sulfide.* (3) Sodium carbonate solution; a basic carbonate is formed (p. 258 of text).

***c.** Devise a process for converting zinc sulfate into zinc chloride. Submit the process to your instructor for approval. When approved, prepare some of the chloride according to your process. For what is the compound used?

EXERCISE 83

ALUMINIUM AND ITS COMPOUNDS

Apparatus. 5 test tubes; blowpipe; burner; 2 beakers; piece of charcoal.

Materials. 1 g. aluminium; hydrochloric acid; ammonium hydroxide; sodium hydroxide; aluminium sulfate solution (R.S.); 2 or 3 drops of cobalt nitrate solution (R.S.); 1 g. sodium carbonate in 5 cc. water; aluminium sulfate and potassium sulfate sufficient to make 20 g. of crystals of potassium alum.

a. Note the physical properties of aluminium. Add 5 cc. of water to a bit of the metal in a test tube and add hydrochloric acid, a drop at a time, sufficient to dissolve the metal. Filter (if necessary) and dilute the solution to about 10 cc. and divide it into two equal parts. To the first add ammonium hydroxide until the solution reacts alkaline (R); to the second add sodium hydroxide, a drop at a time, until a precipitate forms (R). Shake the latter tube and divide the mixture into two equal portions. To the one add hydrochloric acid, noting the result (R); to the other add sodium hydroxide solution until the precipitate dissolves (R). Is aluminium hydroxide an acid or a base?

b. Prepare some aluminium hydroxide by adding ammonium hydroxide to a solution of aluminium sulfate, and heat it on charcoal in the blowpipe flame (R). Moisten the residue with a drop or two of a solution of cobalt nitrate and reheat. Note the result. Advantage is taken of this property in detecting the presence of aluminium.

c. Add a solution of sodium carbonate to a solution of any salt of aluminium. Note that a gas is evolved (?). Devise a method for determining whether or not this gas is carbon dioxide, and make the test.

*d. Calculate the weights of aluminium sulfate (the crystals of aluminium sulfate have the formula $Al_2(SO_4)_3 \cdot 16\,H_2O$) and of potassium sulfate required to prepare 20 g. of crystals of potassium alum; then dissolve these amounts of the two compounds separately in as little water as possible, mix the two solutions thoroughly, and set aside for a few days to crystallize. If a string is suspended in the liquid, the crystals will deposit on it. These may then be withdrawn and their properties studied (?).

EXERCISE 84

A STUDY OF THE USE OF ALUMINIUM SULFATE IN THE PURIFICATION OF WATER

Apparatus. Three 250-cc. wide-mouthed bottles; graduated tube.
Materials. Aluminium sulfate solution (R.S.); limewater (R.S.).

Label the three bottles "A," "B," and "C" respectively. Nearly fill A and B with muddy water, pouring a like volume of distilled water into C. Add 5 drops of aluminium sulfate solution to A and C respectively. Mix the contents of each bottle thoroughly. Now to bottles A and C (each) add 10 cc. of limewater. Set the bottles aside and examine at the beginning of the next laboratory period (?).

EXERCISE 85

REACTIONS OF BAKING-POWDERS

Apparatus. Large test tubes, and corks to fit; stirring-rod.
Materials. 4 g. sodium bicarbonate; limewater (R.S.); alum; cream of tartar; samples of different baking-powders for analysis.

a. Grind together 2 g. of sodium bicarbonate and sufficient (?) alum to react with the bicarbonate. Put the mixture into a large test tube and cover the mixture with water. Cork the tube tightly and shake the mixture. Dip a glass rod into limewater and remove it gently so that a drop of

the clear liquid clings to the end of the rod; then quickly remove the cork from the test tube and lower the end of the rod into the tube (?).

b. Repeat *a*, substituting cream of tartar for the alum (?).

c. What compounds remain in food as a result of the use of an alum baking-powder; of a cream-of-tartar baking-powder?

EXERCISE 86

ANALYSIS OF BAKING-POWDERS (Optional)

Apparatus. 100-cc. beaker; stirring-rod; evaporating-dish; ring stand and burner; 5 test tubes.

Materials. Barium chloride solution (R.S.); sulfuric acid; nitric acid; ammonium molybdate solution (R.S.); sodium hydroxide solution.

a. Introduce 10 g. of a baking-powder into a beaker and pour over it 50 cc. of water. Stir the mixture thoroughly until no more gas is evolved, then filter it, and test the residue and the filtrate for the various ingredients, as explained below.

b. Starch. Will this be in the residue or in the filtrate? Make appropriate test (?).

c. Sulfates. If the baking-powder contains alum, the filtrate will contain sulfates (p. 330 of text). Make appropriate test (?).

d. Tartrates. Pour 5 cc. of the filtrate into an evaporating-dish, add 5 drops of sulfuric acid, and evaporate to dryness. Finally, heat the dish gently with a bare flame. The presence of a tartrate is indicated by an odor similar to that of burning sugar.

e. Phosphates. If calcium phosphate is present in the baking-powder, the filtrate will contain calcium acid phosphate. To detect phosphates, treat 5 cc. of the filtrate with a few drops of nitric acid, heat nearly to boiling, add a few drops of the mixture to 5 cc. of ammonium molybdate solution (?) (compare Exercise 64).

f. Ammonium salts. Ammonium alum is sometimes used in baking-powders. To detect this, pour 5 cc. of the filtrate into a test tube, add an equal volume of sodium hydroxide solution, and heat gently. If ammonium salts are present, ammonia will be evolved (?) (Exercise 74).

g. Aluminium and calcium. A baking-powder containing sulfates always contains aluminium, while one containing phosphates always contains calcium; hence the presence or absence of these metals may be inferred from the tests made for sulfates and phosphates respectively.

EXERCISE 87

THE USE OF MORDANTS IN DYEING

Apparatus. 200-cc. beaker; ring stand and burner; stirring-rod; large beaker.

Materials. 2 strips (2 cm. × 6 cm.) of white woolen cloth (nun's veiling serves well); 6 strips of white cotton cloth (cheesecloth will do); 1 g. sodium carbonate in 50 cc. water; 0.5 g. tannic acid in 50 cc. water; 0.2 g. tartar emetic in 50 cc. water; 0.1 g. of any of the following dyes in 100 cc. water (different students should select different dyes and compare results): fuchsine, methyl violet, Bismarck brown, malachite green; a solution containing 1 g. sodium carbonate, 5 g. Glauber's salt, and 0.1 g. Congo red in 50 cc. water.

a. Most dyes will dye animal fibers (wool, silk) directly, but will dye vegetable fibers (cotton, linen) fast only when mordants are used (p. 331 of text).

Place the strips of cotton cloth in a beaker and cover them with the sodium carbonate solution (1 g. in 50 cc. of water) and boil the liquid for five minutes. Remove the strips and thoroughly rinse them with water. This treatment serves to remove all foreign matter from the cloth.

Now *completely immerse* strips of the cotton cloth in the tannic-acid solution, heat until it is fairly warm to the hand (50° or 60°), and maintain the temperature for ten minutes.

Now remove the cloth from the solution, and squeeze out the liquid, but do not rinse the cloth; then immerse the strips for one minute in the slightly warmed solution of tartar emetic. The tannic acid in the cloth reacts with the tartar emetic, forming a salt (known as antimonyl tannate) which becomes incorporated in the meshes of the fiber and serves as a mordant. Remove the cloth from the solution and rinse it.

Divide the solution of the dye chosen into three equal portions. Heat one portion to boiling, immerse a strip of *woolen* cloth, and continue the heating for from one to two minutes; then remove the cloth and rinse it thoroughly. To test whether the cloth is dyed fast, rinse it thoroughly and then wash it in a beaker of water and note whether the water becomes colored (?). In a similar way dye a strip of *unmordanted* cotton cloth in the second portion of the dye and a strip of *mordanted* cloth in the third portion, and determine in each case whether the cloth is dyed fast (?). Finally, dry the three strips of cloth and insert them in your notebook.

b. Some dyes (known as *substantive dyes*) have the property of dyeing cotton fast without the use of mordants. The so-called "Diamond Dyes for Cotton," which may be purchased at any drug store, belong to this class. Congo red is a typical dye of this class.

Heat the solution of Congo red to boiling, immerse in it a strip of *wet* unmordanted cotton, and continue the boiling for one or two minutes. Remove the cloth, rinse, and test to see whether the cloth is dyed fast. Dry the strip and insert it in your notebook. (The sodium carbonate and the sodium sulfate assist in the process, but do not act as mordants.)

(Save the remaining strips of cotton for use in Exercise 88.)

EXERCISE 88

A STUDY OF LAKES; ALSO THE EFFECT OF USING DIFFERENT MORDANTS WITH THE SAME DYE (Optional)

Apparatus. Two 250-cc. wide-mouthed bottles; evaporating-dish; 2 small beakers; ring stand; burner; stirring-rods.

Materials. 5 cc. of a 20 per cent solution of alizarin paste; solutions of aluminium sulfate and ferric sulfate (R.S.); ammonium hydroxide; 2 strips of cotton cloth.

a. Formation of lakes. Label two wide-mouthed bottles "A" and "B" respectively. Into each introduce about 10 drops of the alizarin paste. Next add to each of the bottles 2 cc. of ammonium hydroxide and then 200 cc. of water, and mix the contents thoroughly. Now add 10 cc. of aluminium sulfate solution to bottle A, and 10 cc. of ferric sulfate to bottle B and set the bottles aside; note the appearance of the contents at the end of the laboratory period, also at the beginning of the next laboratory period (?). What is the function of each of the materials used?

b. Mordanting strips of cloth with aluminium hydroxide and ferric hydroxide. Pour about 20 cc. of aluminium sulfate solution into a small beaker and heat to boiling. Completely immerse in this solution one of the strips of cotton cloth prepared in Exercise 87, and continue the heating for from two to three minutes. Remove the cloth, squeeze it between the fingers to remove the excess of the solution, and immerse it in 20 cc. of water containing from 1 to 2 cc. of ammonium hydroxide. Warm the liquid slightly for two minutes, then remove the cloth and rinse it twice in water. What compound is now incorporated in the cloth?

Repeat the operation, using a solution of ferric sulfate in place of the aluminium sulfate. The resulting strip of cloth is mordanted with ferric hydroxide.

c. Dyeing the strips of mordanted cloth with alizarin. Pour 1 cc. of alizarin paste into a small beaker, add 20 cc. of water, stir, and heat to boiling. Completely immerse one of the strips of mordanted cloth prepared in *b* and continue the heating and stirring for three minutes; then remove the cloth and rinse thoroughly. Repeat the operation, using the second strip of mordanted cloth prepared in *b*. Dry the dyed strips and insert them in your notebook.

EXERCISE 89

THE DETECTION OF DYES IN FOODS (OPTIONAL)

Apparatus. Small beaker; stirring-rod; ring stand and burner.

Materials. Samples (colored) of pop and candy; strips of woolen cloth; hydrochloric acid.

Select different samples of colored pop. Pour 50 cc. of each into a beaker, add 2 or 3 drops of hydrochloric acid, and heat to boiling; then introduce a strip of woolen cloth and continue the heating for five minutes. Remove the cloth, rinse, and note the color (?).

Samples of colored candies may be tested by first dissolving the candy in water and then testing the solution for dyes by using strips of woolen cloth, as in the above case.

Tomato catchup is sometimes colored, although the practice is forbidden by federal law. To test a catchup for dyes, heat a portion of the catchup diluted with water and immerse a strip of woolen cloth in the hot mixture for five minutes. Remove the cloth and rinse thoroughly. If artificial dyes are present, the cloth will be deeply colored; otherwise it will have only a slight brownish tinge produced by the natural coloring-matter of the tomato.

EXERCISE 90

A STUDY OF IRON AND ITS COMPOUNDS

Apparatus. 2 beakers; watch glass; funnel; flask (250-cc.); 8 test tubes; ring stand and burner.

Materials. 5 g. of small tacks or fine iron wire; 0.5 g. powdered iron; filter paper; hydrochloric acid; sulfuric acid; nitric acid; ammonium hydroxide; potassium ferrocyanide (R.S.); potassium ferricyanide (R.S.); potassium sulfocyanide (R.S.).

a. Heat a piece of watch spring (from 10 to 15 cm. in length) to a white heat in a Bunsen flame. Let it cool slowly, and when cold bend it to determine if it is brittle (?). Again heat and *at once* plunge into a beaker of cold water. Bend the piece as before (?). Reheat the piece, allow it to cool slowly, and again examine it (?).

b. Place 5 g. of fine iron wire or small tacks in a beaker and pour over it 15 cc. of water. Now add 4 cc. of concentrated sulfuric acid and heat very gently (hood) until a vigorous evolution of gas takes place (R), then cover the beaker with a watch glass and set it aside in the hood until near the end of the laboratory period. Then add 10 cc. of water and heat slowly until the liquid boils, stirring the mixture constantly. Filter off any undissolved solids, collecting the filtrate in a beaker. Set the filtrate in your desk until the next laboratory period; then examine the crystals (?).

c. Place about 0.5 g. of iron powder in a small flask, pour over it 5 cc. of water, and then from 1 to 2 cc. of hydrochloric acid. Mix the contents of the flask, heat the flask slightly, and set aside in the hood for five minutes (?). Add 50 cc. of water, mix well, and filter. Divide the filtrate into two equal parts. Mark one of these "A" and set it aside. Add to the other portion about 1 cc. of hydrochloric acid and heat it nearly to boiling; then withdraw the flame and add nitric

acid (about 2 cc. of the concentrated acid will be required) a drop at a time, with constant stirring, until the solution, which is at first dark brown, becomes light yellow in color (?). Cool the resulting solution. Call this solution "B". How do solutions A and B differ in composition? Now compare the action of the following reagents upon solutions A and B (add 2 or 3 drops of the reagents to 5 cc. of the solutions in test tubes): ammonium hydroxide, potassium ferrocyanide, potassium ferricyanide, potassium sulfocyanide (KCNS). Tabulate your results as follows:

	Ferrous Chloride (Solution A)	Ferric Chloride (Solution B)
Ammonium hydroxide . . .		
Potassium ferrocyanide . . .		
Potassium ferricyanide . . .		
Potassium sulfocyanide . . .		

EXERCISE 91

THE REMOVAL OF STAINS

Apparatus. 4 test tubes; 2 beakers; evaporating-dish.

Materials. 0.2 g. tannic acid dissolved in 10 cc. water; ferric sulfate (R.S.); 2 pieces of white cloth 10 cm. square; 1 g. oxalic acid dissolved in 50 cc. water; hydrochloric acid; 2 strips of black cloth 5 cm. square; nitric acid; ammonium hydroxide; a few drops each of cottonseed oil and sirup (molasses); 25 cc. carbon tetrachloride; blotting-paper; strips of cloth stained with coffee and fruit juice; acetic acid (R.S.); 20 g. bleaching-powder; hot water.

a. Stain two strips of white cloth by dipping them into a solution of ferric sulfate until thoroughly saturated and then into a solution of tannic acid (or they may be stained directly with black ink). Wash one of the strips repeatedly with boiling water (?). Leave the other exposed to the air until dry; then try the effect of hot water upon the stain. If the stain is

not removed, wash with a dilute solution of oxalic acid and finally with hot water (?).

b. Place 2 or 3 drops of dilute hydrochloric acid upon a strip of black cloth (?). Wash the spots with 10 cc. of water containing 4 or 5 drops of ammonium hydroxide (?). Repeat, using nitric acid in place of hydrochloric acid (?).

c. Place in separate test tubes 4 or 5 drops of a sirup and a like amount of fat, such as cottonseed oil. Test the solubilities of each in water and in carbon tetrachloride. Suggest a method for removing stains made by sirups and one for those made by fats. Stain some strips of cloth with sirup and with an oil and test your methods for removing these stains. (In applying a solvent it is convenient to place the stained portion of the cloth over a piece of blotting-paper (?). A small bit of sponge or cloth, saturated with the solvent, is then rubbed about the stained portion, gradually nearing the stain itself, which is finally thoroughly rubbed.)

Benzine (or gasoline) may be used in place of the carbon tetrachloride. *If benzine is used, however, it must be remembered that it is very inflammable. Never use it in the vicinity of a flame.*

d. Stain some strips of cloth with coffee and with fruit juices. Are the stains removed by washing with hot water? If the stain cannot be removed in this way, wash the stained portion of the cloth in bleaching-powder to which has been added some water and 3 or 4 drops of acetic acid.

EXERCISE 92

THE DETERMINATION OF THE AMOUNT OF WATER OF HYDRATION IN COPPER SULFATE (QUANTITATIVE)

Apparatus. Porcelain crucible; ring stand and burner; pipe-stem triangle; balance; beaker.

Materials. 2 or 3 g. copper sulfate crystals.

Accurately weigh (or counterpoise) a porcelain crucible and cover. Then add 2 or 3 g. of crystals (no larger than a pea)

of copper sulfate and again accurately weigh. Place the covered crucible on a pipe-stem triangle and heat it with a gentle flame until the crystals lose their color. This will require from twenty to thirty minutes. The tip of the flame should not quite touch the crucible. (While the heating is taking place, continue with Exercise 93.) The product is anhydrous copper sulfate. When the crucible is cool, reweigh. From your results calculate the percentage of water of hydration in the crystals. Compare your results with those obtained by other members of the class.

Dissolve the white residue in a little hot water (note the color of the solution) and set the solution aside until the next laboratory period. Examine the product (?).

EXERCISE 93

A STUDY OF COPPER AND ITS COMPOUNDS

Apparatus. 3 test tubes; beaker; ring stand and burner.

Materials. Nail; copper sulfate solution (R.S.); sodium hydroxide; ammonium sulfide (R.S.); ammonium hydroxide; 10 cm. copper wire; hydrochloric acid.

a. Recall the action of nitric acid and of sulfuric acid on copper (Exercises 27, 34); also the action of sulfur and chlorine on copper (Exercises 31, 38). Place a nail in a solution of copper sulfate. Account for the result.

b. To a *cold* solution of copper sulfate add one half its volume of sodium hydroxide solution. Copper hydroxide $Cu(OH)_2$ is precipitated. Now heat to boiling. The hydroxide is decomposed into water and cupric oxide (black).

c. Try the action of ammonium sulfide on copper sulfate (R). Add 1 drop of ammonium hydroxide to a dilute solution of copper sulfate; now continue to add the ammonium hydroxide, drop by drop, until the precipitate which is at first formed is dissolved. How does the color of this solution

compare with that of the original solution? This reaction is characteristic of copper compounds.

d. Recall the formation of cuprous oxide (Exercise 52).

e. Moisten the end of a copper wire with hydrochloric acid and hold it in the edge of a Bunsen flame (?).

EXERCISE 94

A STUDY OF MERCURY AND ITS COMPOUNDS

Apparatus. 100-cc. beaker; 2 test tubes.

Materials. Globule of mercury (size of a grain of wheat); nitric acid; copper penny; 0.5 g. mercuric oxide; 3 cc. solution of mercurous nitrate (R.S.); hydrochloric acid.

a. Note the physical properties of mercury. Place a globule of it in a small beaker and add (hood) just enough nitric acid to dissolve it. Dilute the product with 10 cc. of water and place a copper penny in the solution. After a few minutes remove the coin and polish it with a piece of cloth. Account for the result.

b. For what purpose have we used mercuric oxide? Place 0.5 g. of it in a test tube and dissolve it in as little nitric acid as possible (R). Then add water until the test tube is one-fourth full. Into a second test tube pour a similar volume of a solution of mercurous nitrate. Now add 2 or 3 drops of hydrochloric acid to each test tube (R). What conclusions do you draw in reference to the solubility of the two chlorides of mercury?

EXERCISE 95

A STUDY OF SILVER AND ITS COMPOUNDS

Apparatus. 200-cc. beaker; funnel; blowpipe; 3 test tubes.

Materials. Silver dime; nitric acid; hydrochloric acid; ammonium hydroxide; filter paper; hot water; 2 or 3 g. sodium carbonate; piece of charcoal; 10 cc. silver nitrate solution (R.S.); solutions of potassium bromide and of potassium iodide (R.S.).

a. Place a silver dime in a small beaker and add (hood) sufficient nitric acid to dissolve it. The solution may be hastened by applying a gentle heat. When the solution is complete, dilute the product with about 25 cc. of water. Account for the color of the liquid. Now add a solution of hydrochloric acid until a precipitate ceases to form. On being stirred, the precipitate (?) settles to the bottom of the beaker. Carefully decant the clear supernatant liquid and add ammonium hydroxide until the solution becomes alkaline (*c*, Exercise 93). Wash the precipitate two or three times by pouring hot water over it and decanting. Finally, remove any remaining water by filtration. Mix the product with an equal bulk of sodium carbonate, transfer to a small cavity in a piece of charcoal, and heat it with a blowpipe. The silver salt is gradually reduced to metallic silver, which will fuse into a globule if sufficient heat is applied.

b. Prepare small amounts of the chloride, the bromide, and the iodide of silver (R). Expose to the sunlight the test tubes containing the precipitates and note any changes. For what are these compounds used?

c. Recall the formation of silver sulfide (Exercise 33).

EXERCISE 96

SOME PROPERTIES OF TIN

Apparatus. 100-cc. beaker; piece of charcoal; blowpipe; ring stand and burner.

Materials. 2 pieces of tin (size of a pea); hydrochloric acid; mercuric chloride solution (R. S.).

Note the physical properties of tin (?). Heat a bit of it on charcoal.

Dissolve a small piece of the metal in hydrochloric acid (R). Cool, dilute with a little water, and add 1 or 2 drops of the solution to 3 cc. of mercuric chloride solution. A white precipitate of mercurous chloride forms:

$$SnCl_2 + 2\,HgCl_2 \longrightarrow SnCl_4 + 2\,HgCl$$

Now add a few drops more of the stannous chloride solution and heat the mixture gently. The mercurous chloride is reduced to metallic mercury, which forms a dark-gray precipitate:

$$SnCl_2 + 2\,HgCl \longrightarrow SnCl_4 + 2\,Hg$$

EXERCISE 97

A STUDY OF LEAD AND SOME OF ITS COMPOUNDS

Apparatus. Ring stand and burner; blowpipe; 200-cc. beaker; 5 test tubes.

Materials. 2 g. lead (obtain some scrap lead from a plumber); piece of charcoal; nitric acid; ammonium sulfide (R.S.); sulfuric acid; potassium chromate (R.S.); hydrochloric acid; strip of zinc.

a. Note the physical properties of the metal. Heat a small bit on charcoal. Is it easily melted? Note the coating formed on the charcoal (?).

b. Place about 1 g. of the metal in a beaker (hood) and add 20 cc. of water and 5 cc. of nitric acid. Heat *gently* until the metal is dissolved (?). Dilute to 100 cc. and filter, if necessary, to obtain a clear solution. Call this solution "A." Now test small portions of this solution with ammonium sulfide, sulfuric acid, and potassium chromate (K_2CrO_4) respectively (R). Note the color of the precipitates. Add a few drops of hydrochloric acid to a test tube one-fourth full of solution A. Lead chloride is precipitated. Heat the mixture to boiling, and if the liquid does not become clear, add just enough boiling water to dissolve the precipitate; then set it aside until cool and note the result. How can you distinguish between lead chloride and silver chloride?

In the remainder of solution A suspend a piece of zinc (?).

EXERCISE 98

DETECTION OF SILVER, LEAD, AND MERCURY WHEN PRESENT IN THE SAME SOLUTION (OPTIONAL)

Apparatus. 300-cc. beaker; ring stand and burner; stirring-rod; funnel.

Materials. Solutions of $AgNO_3$, $Pb(NO_3)_2$, and $HgNO_3$ (R.S.); filter paper; potassium chromate (R.S.); sulfuric acid; ammonium hydroxide; nitric acid; hot water.

The detection of any one metal becomes more complicated when other metals are present in the same solution. As a rule it is necessary so to treat the mixture as to separate the metals from each other. The principle involved is illustrated in the following procedure, the solution containing the nitrates of silver, lead, and mercury (*ous*).

Prepare a solution containing 0.2 g. of each of the following compounds: $AgNO_3$, $Pb(NO_3)_2$, $HgNO_3$. Dilute with water to about 200 cc. Precipitate with HCl (R). Filter and fill the paper with boiling water three or four times, collecting the

liquid as it flows from the funnel. This liquid contains the $PbCl_2$ which has been dissolved by the hot water. Its presence may be proved by testing separate portions of the filtrate with solutions of K_2CrO_4 and H_2SO_4 respectively (Exercise 97).

To the residue on the filter paper (of what is it composed?) add 2 or 3 cc. of NH_4OH and collect the liquid as it drops from the funnel. This liquid contains the AgCl dissolved from the residue by the NH_4OH. To prove its presence add HNO_3 to the liquid until just acid to litmus paper. The AgCl is precipitated.

What effect did the NH_4OH have upon the color of the residue on the filter paper? This change in color is due to the action of NH_4OH on the HgCl, and serves as a test for the presence of the latter.

Supposing that the original solution contained only one or two of the metals of the group, how would the absence of the remaining ones be indicated?

EXERCISE 99

A STUDY OF SOME OF THE COMPOUNDS OF MANGANESE

(OPTIONAL)

Apparatus. 6 test tubes.

Materials. 0.1 to 0.2 g. potassium permanganate ($KMnO_4$); crystal of ferrous sulfate; sulfuric acid; ammonium sulfide (R.S.); ammonium carbonate (R.S.); sodium hydroxide; manganese chloride solution (R.S.).

a. Examine the physical properties of potassium permanganate (?). Dissolve about 0.1 g. of it in 5 cc. of water (?). Add a drop of the solution to a solution containing a small crystal of ferrous sulfate and 2 or 3 drops of sulfuric acid. The ferrous sulfate is changed to ferric sulfate, the oxygen in the reaction (see equation below) coming from the potassium permanganate, which is a good oxidizing agent.

$$2\,FeSO_4 + H_2SO_4 + O \longrightarrow Fe_2(SO_4)_3 + H_2O$$

b. In potassium permanganate the manganese acts as an acid-forming element. It also acts as a base-forming element in certain compounds. Try the action of ammonium sulfide, ammonium carbonate, and sodium hydroxide, respectively, on a solution of manganese chloride (?).

EXERCISE 100

A STUDY OF SOME OF THE COMPOUNDS OF CHROMIUM (OPTIONAL)

Apparatus. 6 test tubes.

Materials. Solution of potassium chromate (R.S.); lead acetate solution (R.S.); barium chloride solution (R.S.); ammonium sulfide (R.S.); sodium carbonate solution (R.S.); sodium hydroxide solution; 0.5 g. chromium chloride or chromium sulfate dissolved in 25 cc. water.

a. Chromates and dichromates. Write the formula for potassium chromate; for potassium dichromate. Is the chromium an acid-forming or a base-forming element in these compounds? Add 2 or 3 drops of sulfuric acid to a little potassium chromate solution (?).

b. Try the effect of a solution of potassium chromate on a solution of a compound of lead (R); also on a compound of barium (R).

EXERCISE 101

BORAX-BEAD TESTS (OPTIONAL)

Apparatus. Platinum wire; burner.

Materials. Borax (R.S.); small piece (size of a pin's head) of a compound of each of the following metals: nickel, iron, manganese, copper.

Recall the effect of adding a trace of cobalt nitrate to a borax bead (Exercise 69). Repeat the experiment, substituting for the cobalt nitrate, salts of the following metals: nickel, iron, manganese, copper (?).

APPENDIX A

TABLE OF CONSTANTS

LIST OF THE COMMON ELEMENTS, THEIR SYMBOLS, AND THEIR ATOMIC WEIGHTS

O = 16

Aluminium	Al	27.1	Iodine	I	126.92
Antimony	Sb	120.2	Iron	Fe	55.84
Arsenic	As	74.96	Lead	Pb	207.1
Barium	Ba	137.37	Magnesium	Mg	24.32
Bismuth	Bi	208.0	Manganese	Mn	54.93
Boron	B	11.0	Mercury	Hg	200.6
Bromine	Br	79.92	Nickel	Ni	58.68
Cadmium	Cd	112.4	Nitrogen	N	14.01
Calcium	Ca	40.07	Oxygen	O	16.00
Carbon	C	12.00	Phosphorus	P	31.04
Chlorine	Cl	35.46	Potassium	K	39.1
Chromium	Cr	52.0	Silicon	Si	28.3
Cobalt	Co	58.97	Silver	Ag	107.88
Copper	Cu	63.57	Sodium	Na	23.0
Fluorine	F	19.0	Sulfur	S	32.07
Gold	Au	197.2	Tin	Sn	119.0
Hydrogen	H	1.008	Zinc	Zn	65.37

TENSION OF AQUEOUS VAPOR AT VARIOUS TEMPERATURES, EXPRESSED IN MILLIMETERS OF MERCURY

Temperature	Pressure	Temperature	Pressure
16°	13.6	21°	18.6
17°	14.4	22°	19.8
18°	15.4	23°	21.0
19°	16.4	24°	22.3
20°	17.5	25°	23.7

WEIGHT IN GRAMS OF 1 LITER OF VARIOUS GASES MEASURED UNDER STANDARD CONDITIONS

Acetylene	1.1621	Hydrogen sulfide	1.5392
Air	1.2928	Methane	0.7168
Ammonia	0.7708	Nitric oxide	1.3402
Carbon dioxide	1.9768	Nitrogen	1.2507
Carbon monoxide	1.2504	Nitrous oxide	1.9777
Chlorine	3.1674	Oxygen	1.4290
Hydrogen	0.08987	Sulfur dioxide	2.9266
Hydrogen chloride	1.6398		

THE METRIC SYSTEM

This system is now used in all civilized countries with four or five exceptions. The United States and Great Britain are among the few countries that have not formally adopted it, but even in these countries the system is universally used by scientists and is coming into use more and more by manufacturers.

In the metric system each unit is 10 times as large as the next lower unit; hence the system is often termed the "decimal system."

1. Length. The unit is the *meter*. It is equal to 39.37 inches.

10 millimeters (mm.) = 1 centimeter (cm.)
10 centimeters = 1 decimeter (dm.)
10 decimeters = 1 meter (m.)
1000 meters = 1 kilometer (km.)

The only measures of length ordinarily used by the chemist are the millimeter and the centimeter; thus, the height of the barometer at the sea level is recorded as 76 cm. (or more commonly as 760 mm.), and not 7 dm. and 6 cm.

2. Volume. The unit generally used is the *cubic centimeter*.

1000 cubic millimeters = 1 cubic centimeter (cc.)
1000 cubic centimeters = 1 cubic decimeter = 1 liter
1000 cubic decimeters = 1 cubic meter

The chemist uses only the cubic centimeter and the liter as measures of volume. Thus, the volume of a test tube is given as (say) 25 cc.; that of a flask as (say) 500 cc., or $\frac{1}{2}$ liter.

3. Weight. The unit is the *gram.* This is approximately the weight of 1 cc. of pure water at its temperature of greatest density (4°). It is equal to 15.43 grains.

10 milligrams (mg.) = 1 centigram (cg.)
10 centigrams = 1 decigram (dg.)
10 decigrams = 1 gram (g.)
1000 grams = 1 kilogram (kg.)

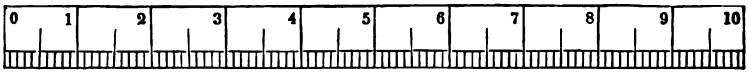
The gram and kilogram are the units of weight most generally used by the chemist. Thus, the weight of a crucible is given as (say) 10.532 g. and not 10,532 mg. or 10 g. 5 dg. 3 cg. 2 mg.

Note that

1 pound troy = 5760 grains = 373.24 grams.
1 pound avoirdupois = 7000 grains = 453.59 grams.
1 ounce avoirdupois = 28.35 grams.
1 U.S. liquid quart = 946.36 cubic centimeters.

Also note that

1 centimeter = nearly $\frac{2}{5}$ inch.
1 meter = nearly 1.1 yards.
1 kilogram = nearly $2\frac{1}{5}$ pounds avoirdupois.



TEN-CENTIMETER SCALE

TABLE OF SOLUBILITIES OF SOME OF THE COMPOUNDS OF THE METALS

	Acetate	Bromide	Carbonate	Chlorate	Chloride	Chromate	Hydroxide	Iodide	Nitrate	Oxide	Phosphate	Silicate (ortho)	Sulfate	Sulfide
Aluminium . . .	W	W		W	W		A	W	W	A	A	A	W	A
Ammonium . . .	W	W	W	W	W	W	W	W	W		W		W	W
Barium	W	W	A	W	W	A	W	W	W	A	A	A	I	W
Calcium	W	W	A	W	W	X	W	W	W	X	A	A	X	X
Cobalt	W	W	A	W	W	A	A	W	W	A	A	A	W	A
Copper	W	W	A	W	W	W	A	W	W	A	A	A	W	A
Ferric	W	W		W	W	W	A	W	W	A	A	A	W	A
Ferrous	W	W	A	W	W		A	W	W	A	A	A	W	A
Lead	W	X	A	W	X	A	A	X	W	A	A	A	I	A
Magnesium . . .	W	W	A	W	W	W	A	W	W	A	A	A	W	A
Manganese . . .	W	W	A	W	W	W	A	W	W	A	A	A	W	A
Mercuric	W	W	A	W	W	X		A	W	A	A		X	I
Mercurous	W	A		W	A	A		A	W	A	A		X	
Nickel	W	W	A	W	W	A	A	W	W	A	A	A	W	A
Potassium	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Silver	W	I	A	W	I	A		I	W	A	A		X	A
Sodium	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Stannic	W	W			W		A	W		A	A			A
Stannous	W	W			W	A	A	W		A	A		W	A
Zinc	W	W	A	W	W	W	A	W	W	A	A	A	W	A

W, soluble in water.

A, insoluble in water, soluble in either HCl or HNO_3 or in both.

I, insoluble in water and in acids.

X, slightly soluble in water and slightly or readily soluble in acids.

APPENDIX B

INFORMATION REGARDING APPARATUS AND CHEMICALS

The lists following include the apparatus and chemicals required for the experiments in this notebook. It is always best to furnish each student with as complete an outfit as possible and to hold him responsible for the same. Certain pieces may, however, be used in common by a number of students, and these have been placed in a separate list. It is always cheapest to purchase the apparatus and chemicals in as large quantities as possible. The amounts of most of the chemicals needed for a class of ten are so small that the cost of the same will be proportionately much greater than when larger quantities are ordered. It is always best to order the definite amounts of chemicals listed in the catalogues, such as 100 g. or 1 lb.; otherwise the cost of weighing out odd quantities and preparing these for shipment may amount to more than the cost of the chemicals. The supplies may be obtained from any of the large dealers. Catalogues will be sent on application and should be in every school. The following are the addresses of some of the largest firms:

Central Scientific Company, 412 Orleans St., Chicago, Ill.

The Kauffman-Lattimer Co., Columbus, Ohio.

Eimer and Amend, 205 Third Avenue, New York City.

Bausch & Lomb Optical Co., Rochester, N.Y.

Arthur H. Thomas Company, West Washington Square, Philadelphia, Pa.

E. H. Sargent & Co., 145 Lake St., Chicago, Ill.

A list of the supplies needed should be sent to a number of firms for quotations on prices. In ordering any piece of apparatus a certain form in some catalogue should be designated; otherwise it will be impossible to compare the prices. In general it is best

to purchase as simple a form of apparatus as possible; for example, 20 cents will buy a Bunsen burner which for ordinary purposes is preferable to those costing $1. In the case of large orders a considerable saving may be made by placing the order four or five months early and requesting the dealer to import duty free such articles as can in this way be obtained at a less cost. A much higher price will have to be paid for small orders placed for immediate delivery. A person experienced in the purchase of supplies will always find it possible to reduce materially the cost of the order.

APPARATUS REQUIRED FOR EACH STUDENT (TO BE KEPT IN STUDENT'S LOCKER)

Beakers, nest of 7 (100-cc. to 700-cc.).
Blowpipe, mouth.
Bottle, narrow-necked, 1000-cc. (Fig. 25, *B*).
Bottles, wide-mouthed: 1 (60-cc.); 5 (250-cc.).
Burner, wing-top, for bending glass tubing (Fig. 10).
Calcium chloride drying-tube, straight, 15 cm. in length (Fig. 19, *B*).
Charcoal, 1 piece 8 cm. × 3 cm.
Deflagrating-spoon.
Dish, lead, diameter about 6 cm., depth 3 cm.
Evaporating-dish, diameter 7 cm.
File, round, about 15 cm. in length.
File, triangular, about 15 cm. in length.
Filters, 25, diameter about 11 cm.
Flasks: 2 (250-cc.); 1 (500-cc.).
Funnel, diameter about 6.5 cm.
Funnel tube, external diameter of tube 6 mm.
Glass tubing, 200 g., soft, external diameter 6 mm., walls 1 mm. thick.
Glass tubing, hard, internal diameter 1 cm., 1 piece 30 cm. in length.
Glass tubing, hard, internal diameter 6 mm., 1 piece 20 cm. in length.
Glass rod, diameter 3 mm., 1 piece 15 cm. in length.
Glass rod, 1 piece 10 cm. in length.
Mortar (diameter about 8 cm.) and pestle (both of porcelain).
Pipe-stem triangle, for holding porcelain crucible (Fig. 2).
Platinum wire, small (No. 28), 8 cm. long, for flame tests.
Porcelain crucible and lid, diameter about 3.5 cm.
Retort, glass-stoppered, 150-cc. (Fig. 30).

Rubber tubing, internal diameter 6 mm., 1 piece 50 cm. in length.
Rubber tubing (soft), pure gum, internal diameter 5 mm., 1 piece, 60 cm. in length, for connections, etc.
Splints (ordinary cigar lighters), 125.
Sponge.
Stopper, rubber, one-hole, to fit hard-glass test tube.
Stopper, rubber, two-hole, to fit wide-mouthed 250-cc. bottle.
Stopper, rubber, two-hole, to fit wide-mouthed 60-cc. bottle.
Stopper, rubber, two-hole, to fit 1000-cc. narrow-mouthed bottle.
Test tube, graduated, 30-cc., about 20 cm. long, with 0.5-cc. graduations.
Test tube, hard glass, preferably Jena glass, 15 cm. in length, diameter about 1.8 cm.
Test tubes, 12, length 12 cm., diameter about 1.7 cm.
Test-tube brush.
Test-tube rack.
Towel.
Watch glass, diameter about 8 cm.
Window glass, 4 pieces 10 cm. square.
Wire gauze, 2 pieces 12 cm. square.

APPARATUS TO BE LEFT ON EACH DESK

Bunsen burner, with 75 cm. of rubber tubing to fit.
Clamp, iron, large, for holding flasks and condensers.
Iron tripod (Fig. 31).
Pneumatic trough (Fig. 18). The trough should be about 12 to 15 cm. deep, and large enough to hold 4 or 5 wide-mouthed bottles (250-cc.). It may be round or rectangular. A pan made of granite ware or an earthen crock serves well, or any tinsmith can readily make suitable troughs of galvanized iron.
Ring stand and 3 rings.

REAGENTS ON EACH DESK

250-cc. bottles filled with the reagents named below. The bottles containing the sodium hydroxide should have ordinary corks, the others should be glass-stoppered.
Ammonium hydroxide (density 0.90).
Hydrochloric acid (density 1.2).
Nitric acid (density 1.4).
Sodium hydroxide solution (10 g. in 100 cc. of water).
Sulfuric acid (density 1.84).

GENERAL APPARATUS FOR TEN STUDENTS[1]

*2 sets apparatus for testing conductivity of solutions (Fig. 53, p. 103, "First Course in Chemistry"); this may be purchased of supply houses.
1 balance, weighing from 0.5 g. to 500 g., with accompanying weights.
2 balances, sensitive to 1 cg. and made to carry a load of 100 g.
1 barometer.
1 bottle or flask, 2000-cc. (Fig. 40, *A*).
4 burettes, 50-cc., graduated in 0.1 cc. (Fig. 28).
5 pieces cobalt glass 10 cm. square (for flame tests).
*4 condensers, Liebig (Fig. 25, *B*, p. 42, "First Course in Chemistry"), with rubber tubing and large clamp.
2 sets cork-borers (6 in a set).
2 gross corks, best grades, sizes 7, 8, 9, 10, and 12.
1 cylinder, glass, about 30 cm. in length and 4 to 5 cm. in width.
1 cylinder, graduated, 200-cc.
1 cylinder, graduated, 500-cc.
1 distilling apparatus for preparing distilled water.
*2 flasks, holding 100 cc. when filled to point marked on neck (Fig. 41, *C*).
*1 hydrometer, reading from 0.900 to 1.000.
1 magnifying-glass, small.
*1 microscope, eyepiece 1 inch, objectives $\frac{2}{3}$ and $\frac{1}{6}$.
5 thermometers, graduated from $-10°$ to $+150°$C.
2 tubes, graduated in cubic centimeters, 50 cm. in length and about 2 cm. in width.
2 sets weights, 1 cg. to 50 g., in covered wooden box.

CHEMICALS ON REAGENT SHELF (FOR USE OF ALL STUDENTS)

The bottles containing solutions should be glass-stoppered. Gummed letters of the alphabet, of different sizes, may be obtained at little cost from any stationer, and these may be used in making the labels for the bottles. If the class is small, bottles holding 250 cc. will ordinarily serve; if the class is large, then it is better to use bottles holding at least 500 cc. A few of the reagents, such as limewater, are used so extensively that it is better to use a 1000-cc. bottle. Distilled water must be used in making all solutions. A 10% solution signifies 10 g. dissolved in 100 cc. of water.

[1] Apparatus marked by a star (*) is desirable but not necessary unless all optional experiments are performed.

Acetic acid (36%).
Alcohol (95%).
Aluminium sulfate (10% solution).
Ammonium carbonate (25 g. of the solid dissolved in 70 cc. of water and 10 cc. of ammonium hydroxide (density 0.90) and the solution diluted to 100 cc. with water).
Ammonium chloride (10% solution).
Ammonium molybdate solution.
Ammonium sulfide solution.
Barium chloride (10% solution).
Borax (solid).
Calcium chloride (10% solution).
Carbon tetrachloride.
Cobalt nitrate (5% solution).
Copper sulfate (10% solution).
Disodium phosphate (10% solution).
Ferric chloride (10% solution).
Ferric sulfate (10% solution).
Lead acetate (10% solution).
Limewater (saturated solution of calcium hydroxide).
Magnesium sulfate (10% solution).
Manganese chloride (10% solution).
Mercuric chloride (5% solution).
Mercurous nitrate (10% solution).
Phenolphthalein (1 g. dissolved in 200 cc. of alcohol).
Potassium bromide (10% solution).
Potassium chromate (10% solution).
Potassium ferricyanide (10% solution).
Potassium ferrocyanide (10% solution).
Potassium hydroxide (10% solution).
Potassium iodide (10% solution).
Potassium sulfocyanide (10% solution).
Silver nitrate (4% solution).
Starch solution (prepared by rubbing to a paste 4 or 5 g. of starch with cold water, and then adding, 3 or 4 drops at a time and with stirring, to 1 liter of boiling water. Add also about 10 g. of zinc chloride (this acts as a preservative). Mix thoroughly, set the mixture aside, and use the clear supernatant liquid).
Sodium carbonate (10% solution).
Sodium chloride (solid).
Zinc acetate (10% solution).

CHEMICALS REQUIRED FOR A CLASS OF TEN

The terms in parentheses after the names of the chemicals refer to the grade of materials to be purchased. The abbreviation c.p. signifies "chemically pure."

	Approximate Amounts
Acid, acetic (36%) (c.p.)	1 lb.
Acid, hydrochloric (density 1.2) (c.p.)	6 lb.
Acid, nitric (density 1.4) (c.p.)	7 lb.
Acid, oxalic (pure)	½ lb.
Acid, pyrogallic	¼ lb.
Acid, sulfuric (density 1.84) (c.p.)	9 lb.
Acid, tannic (commercial)	¼ lb.
Alcohol (95%)	1 qt.
Alum (ammonium) (pure)	1 lb.
Aluminium (turnings or filings)	1 oz.
Aluminium sulfate (pure, crystals)	1 lb.
Ammonium carbonate (pure)	¼ lb.
Ammonium chloride (pure)	½ lb.
Ammonium hydroxide (density 0.90) (c.p.)	4 lb.
Ammonium molybdate solution	1 lb.
Ammonium nitrate (pure)	¼ lb.
Ammonium sulfate (commercial)	1 lb.
Ammonium sulfide solution	1 lb.
Antimony	1 oz.
Arsenic	1 oz.
Arsenic trioxide (arsenious oxide) (commercial)	1 oz.
Barium chloride (c.p.)	¼ lb.
Bismuth	1 oz.
Bleaching-powder	1 lb.
Bone black	½ lb.
Borax (commercial)	1 lb.
Boric acid (pure)	¼ lb.
Cadmium	½ oz.
Cadmium chloride (c.p.)	1 oz.
Calcium carbide	1 lb.
Calcium carbonate (precipitated)	1 lb.
Calcium chloride (fused or granular)	2 lb.
Calcium fluoride (fluorspar)	½ lb.
Calcium hydroxide (hydrated lime)	1 lb.
Calcium sulfate (plaster of Paris)	5 lb.
Carbon disulfide (commercial)	1 lb.
Carbon tetrachloride (commercial)	1 lb.

Cobalt nitrate (pure)	1 oz.
Copper (turnings or scrap)	½ lb.
Copper foil (thin)	¼ lb.
Copper nitrate (pure)	1 oz.
Copper oxide (black, ordinary)	2 oz.
Copper sulfate crystals (c.p.)	½ lb.
Cottonseed oil	½ lb.
Dyes (Bismarck brown, fuchsine, methyl violet, malachite green, Congo red)	10 g. of each
Alizarin paste (20%)	¼ lb.
Formalin	¼ lb.
Glucose (sirup) or Karo corn sirup	2 lb.
Gypsum (crystals)	½ lb.
Hydrogen peroxide	½ lb.
Iodine	1 oz.
Iron chloride (ferric) (c.p.)	2 oz.
Iron powder (iron reduced by alcohol)	4 oz.
Iron sulfate (ferrous)	½ lb.
Iron sulfide	2 lb.
Iron wire (picture-frame wire), No. 0	25 yd.
Junket tablets	10 tablets
Lead acetate (sugar of lead) (powdered)	½ lb.
Lead monoxide (commercial)	4 oz.
Lead nitrate (pure)	2 oz.
Litmus cubes	2 oz.
Litmus paper — 100 strips red, 100 strips blue	1 tube of each
Magnesium carbonate (powdered)	4 oz.
Magnesium sulfate (Epsom salts)	1 lb.
Magnesium wire or ribbon	1 oz.
Manganese chloride	2 oz.
Manganese dioxide (commercial)	2 lb.
Marble (pieces size of a walnut)	5 lb.
Mercuric chloride (corrosive sublimate)	1 oz.
Mercuric nitrate (c.p.)	1 oz.
Mercuric oxide	1 oz.
Mercurous nitrate (c.p.)	4 oz.
Mercury	1 oz.
Nickel nitrate	1 oz.
Paraffin	1 lb.
Phenolphthalein	1 oz.
Phosphorus	1 oz.
Potassium bitartrate (cream of tartar)	¼ lb.

Potassium bromide (granular, pure)	2 oz.
Potassium carbonate (c.p.)	2 oz.
Potassium chlorate (small crystals)	1 lb.
Potassium chloride (c.p.)	¼ lb.
Potassium chromate (pure, crystals)	4 oz.
Potassium chromium sulfate (chrome alum)	4 oz.
Potassium dichromate (pure)	¼ lb.
Potassium ferricyanide (c.p.)	4 oz.
Potassium ferrocyanide (c.p.)	4 oz.
Potassium hydroxide (sticks, electrolytic)	½ lb.
Potassium iodide (pure)	2 oz.
Potassium nitrate (pure)	½ lb.
Potassium permanganate (pure)	1 oz.
Potassium sulfate (pure, anhydrous)	½ lb.
Potassium sulfocyanide (c.p.)	1 oz.
Silver nitrate	1 oz.
Soda lime (granular)	1 lb.
Sodium	1 oz.
Sodium acetate (fused)	½ lb.
Sodium benzoate (pure)	1 oz
Sodium bicarbonate (baking-soda)	1 lb.
Sodium carbonate (pure, anhydrous)	½ lb.
Sodium hydrogen phosphate (disodium phosphate) (c.p.)	4 oz.
Sodium hydroxide (sticks, electrolytic)	2 lb.
Sodium nitrate (pure)	½ lb.
Sodium potassium tartrate (Rochelle salts) (powdered)	1 lb.
Sodium silicate solution (water glass)	1 lb.
Sodium sulfate (crystals)	½ lb.
Sulfur	1 lb.
Tartar emetic (potassium antimonyl tartrate)	2 oz.
Tin (granulated)	2 oz.
Zinc (granulated, arsenic-free)	2 lb.
Zinc (sheet)	½ lb.
Zinc acetate (c.p.)	1 oz.
Zinc chloride	¼ lb.
Zinc sulfate (crystals)	¼ lb.

NOTE. This does not include substances always easily obtained, such as sugar, salt, lard, lime, clay, coal, cotton, iron wire, calico strips, lead (pieces cut from lead pipe), soap, kerosene, gasoline, candles, cardboard, starch, cloth, milk, vinegar, butter, etc.